SMALL BOAT BUILDING

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TORONTO

SMALL BOAT BUILDING

BY
H. W. PATTERSON

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INTRODUCTION

During recent years motor boating has grown apace, so that hundreds of boats are now seen where twenty years ago power driven craft were novelties. The fleet of good old wind-jammers has also grown, many of which are now equipped with engines, making it possible for the man with limited time to enjoy the sport with assurance of getting home regardless of wind. With this growth, numerous magazines have been published in the interest of the sport and these, being educational in character, have removed much of the mystery previously supposed to surround boat building. As a result amateur building has become popular, and many creditable boats are turned out. Nevertheless boat building still remains an art and unless the novice has access to a shop where he can see the actual work performed, and obtain professional advice, he must resort to printed matter for help. Many good articles have been published, but these are scattered through numerous magazines, and generally apply to one particular boat, so I feel there is

room for a hand book from a practical man, giving general information of benefit to the amateur. The idea is, not to describe the building of any one boat, but to treat the various parts separately, explaining methods of construction and giving suggestions for their application.

The building of a punt or flat bottomed skiff is comparatively easy and may be attempted by nearly every one, but to build a V or round bottomed boat successfully, the amateur must have some knowledge of form and construction, understand the use of tools, and be a fair workman. As nearly all the joints are the junction of curved surfaces and require to be strong and watertight, it is quite evident that more skill and nicety of fitting are required than for plain carpentry.

It is impossible in a book of this size to discuss boat building thoroughly, and only those things which apply directly to the class of boats the amateur is likely to attempt have been considered. In order to cover the subject, the text has been made as simple and concise as possible, but it is hoped that a study of the plates in connection with it will make matters plain. Hull construction only has been dealt with, but if the novice gets this far, the details of interior work can easily be obtained by inspection of some completed boat.

Even for the simplest boat, drawings showing the dimensions and form of hull and the general arrangement are required. Construction plans, showing the arrangement and sizes of all parts, are also desirable but not absolutely necessary for small boats. However, unless the amateur is familiar with such things, he should obtain this information from the designer or a practical builder. Plans may be obtained from a designer or taken from some magazine, if published for that purpose.

As the greenest kind of an amateur, I once built a small, round bottomed, decked sail boat. Innumerable difficulties were finally overcome and the job completed to my satisfaction, but many things were done twice, some three times. So in preparing this book I have endeavored to keep these difficulties in mind and give such information as would have helped me most at that time.

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CHAPTER I

TOOLS

MOST of the tools used in boat work are those with which every one is familiar and little need be said regarding them. Good work cannot be done with poor or dull tools, so get the best and keep them in order. Diston saws, Stanley planes, Buck Bros. chisels, and Jennings' bits are all reliable. There may be others equally good but these are old makes and have stood the test of time. There are, however, a few tools peculiar to this class of work about which brief mention will be made.

Broad Axe. This axe differs considerably from the ordinary tool used for chopping. The blade is wide and sharpened by beveling one side more than the other, somewhat like a chisel. Both blade and handle are offset, the whole form and

hang being adapted to hewing on the side of large material.

Adze. A tool resembling a hoe and used in much the same manner for shaping large parts where the wood to be removed is too much for chisel or plane. The lipped adze has the extreme ends of blade turned up and is by far the best kind as these lips insure a clean cut and prevent raising splinters. For best results the cut is made across the grain.

For converting large material when machinery is not available the roughing is done with a broad axe; the adze is next used to get close to the finished dimensions, and the work is smoothed up with a plane.

Maul. A heavy long-handled hammer with a round pene, used for driving large fastenings, wedges, etc., and is also useful for holding on when driving or riveting some types of fastenings.

Riveting Tools. The best hammer for riveting all types of fastenings is the ball pene machinist's hammer. All riveted fastenings should have the heads formed over burrs or washers and a set is necessary to drive these on. This is a blunt tool with a hole in the end, which can be bought, or if the burrs are not too small a piece of iron pipe 4″ to 6″ long answers very well.

Caulking Mallet. This tool is used in connec-

tion with caulking irons for driving cotton or oakum into seams to make them watertight. The head, which is long and of small diameter, is usually made of live oak and fitted with iron rings to add weight and prevent splitting. Several sizes are made, the smallest being suitable for boat work.

Caulking Irons are made in various shapes and sizes. The two in general use are the dumb iron which has a tapered blade, almost sharp, and the making iron which has a square blunt edge ($\frac{1}{16}$″ or less for boat work). The dumb iron is employed to open up seams that are too tight and the making iron is used to drive in the caulking. A caulking wheel is a thin metal disc mounted in a handle so it can revolve. The edge is fairly sharp and it is used in light work to open the seams, also to roll in the cotton.

Augers and Bits. Common auger bits are used for boring miscellaneous short holes from $\frac{1}{4}$″ diameter up and countersinking for plugs. A better bit, however, for countersinking is the Forstner which has no worm or side cutters.

Ship augers are used for long holes. They are of different shape and made with and without a feed screw or worm. Those without worm, sometimes called "bare footed," are preferred for very long holes as they are not so readily deflected from

a straight course. The commercial bit is often too short, but it is a small job for a blacksmith to weld in a piece making any length required.

For medium sized fastenings the ordinary gimlet bit is suitable and these may also be lengthened. For small fastenings common twist drills used in a hand drill are the fastest and best.

Clamps. These are made of both wood and iron in a variety of forms and are invaluable for temporarily holding parts in place while fitting and fastening. The plain iron screw clamp will be found the most useful and a dozen or more of suitable size should be on hand.

CHAPTER II

WOODS

THE author appreciates the limitations of this chapter. The woods described are those used by boat builders in the north-eastern part of the United States and are admirable in every way. In the extreme south, parts of the west, and other countries, these may not be readily procured and in such places the builder must be governed by local practice and markets.

Timber when cut contains thirty to fifty per cent. of moisture, the greater portion of which evaporates as the wood seasons. Air seasoning takes two to eight years depending on the kind of wood and size, but this time may be shortened by immersion in water for several months which dissolves and drives out the sap. This is the method employed by shipyards for large timbers. Oak so seasoned is less liable to warp and check and before the water dries out cuts very easily.

Lumber for hulls should not be too dry, otherwise it will swell excessively and in some cases

make trouble. Lumber for decks, outside finish and interior joiner work should be thoroughly air seasoned and then well protected with paint or varnish to keep the moisture out. Material made bone dry in a kiln is not desirable for any part as

FIG. 1.

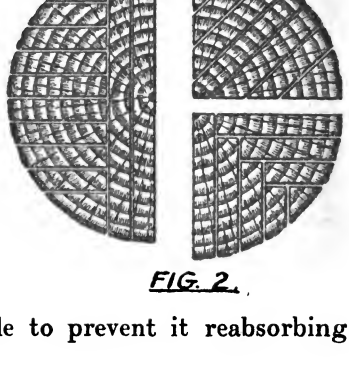


FIG. 2.

it is almost impossible to prevent it reabsorbing some moisture.

Unfortunately wood shrinks during the process of seasoning and this shrinkage is likely to cause warping and *checks* unless precautions are taken to prevent. The greatest shrinkage is in a direction parallel to the annual rings, so that lumber sawed as in Fig. 1, has a tendency to warp as shown, while if sawed in either of the ways shown in Fig. 2, known as "quarter sawing," the shrinkage simply reduces the thickness, and the material is better in every way. Decking should always

be quarter sawed and laid with the edge grain up.

All material for boat work should be looked over carefully for defects such as large, loose, or rotten knots, worms, large checks, rot or yellowish stains, which are usually the first indication of rot. No hard and fast rules can be laid down as some of these defects are only comparative. For instance, a knot or check unobjectionable in a keel 6″ wide would spoil the keel for a light runabout, or knots passing rigid inspection in planking 1″ thick would not do at all in planking $\frac{5}{16}$″ thick.

In order to understand the following descriptions let us first consider the physical make-up of the growing tree. Outside is the bark which does not concern us. Next to this is the sap wood, the part through which most of the sap flows to the branches and leaves. It is lighter in color than the heart and varies in different species from $\frac{1}{2}$″ to 3″ wide. With the exception of elm it is the least durable part of the wood and should not be used if the best possible boat is desired. Inside the sap is the heart wood and in the center of this the pith. In most trees this pith is unnoticeable; however, the wood in the center of a tree is liable to be uncertain and disturbed so that if used it should be enclosed or "boxed in" and not show on the surface.

Looking at the end of a log we see lines running parallel to the outside which are the annual rings, one being added for each year's growth. In trees of rapid development these rings are wide which makes what is commonly known as coarse grain, the opposite of fine grain when they are narrow. Strictly speaking the grain of wood is not the width of the annual rings, but the structural composition of its fibers and vessels, and this meaning will be used in the following descriptions.

No exact data can be given as every kind has several varieties and the characteristics vary considerably. Even woods of the same variety differ greatly, depending on the soil, elevation, proximity to the coast, etc. Then again a single species may be known by a dozen or more names which is especially true in regard to the pines. The varieties described are the most desirable for boat work, but if they cannot be obtained the builder must content himself with the next best. Weights are given for one cubic foot of dry wood and some comparison of strength is indicated by the weight.

White Oak. 47 lbs.; color, light yellow; grain, fine; hard, tough, strong, durable, holds fastenings well and bends readily when steamed. The best wood for keels, stems, shaft logs, frames, floors, sheer strakes, planksheers, center-boards, rudders, and in fact for every part where strength

is essential. It is also used for interior and exterior finish, but is not as desirable for outside work, to be finished bright, as mahogany or teak. Unless perfectly protected with varnish it will turn black in places, especially at ends and around plugs and fastenings. It is sometimes used for planking, but its tendency to shrink and swell makes it undesirable for small boats that are hauled out in the winter. Any size or length required may be obtained.

White Elm. 41 lbs.; color, light yellow; grain, fine and straight; strong, tough, and durable. Elm resembles oak and may be used for the same purposes. When steamed it becomes very pliable and can be bent more than oak.

Yellow Pine (long leaf). 44 lbs.; color, light reddish brown; grain, fine and straight; strong, medium hard, resinous, and very durable. Except for the lightest hulls it is the best wood for keelsons, stringers, clamps, etc., and when weight is not an objection it is a splendid planking material. Used also for planksheers, floor beams, flooring, watertight bulkheads, and sheathing. While not nearly as good as oak it can be used as a substitute except for steam bent frames. It can be obtained in almost any size or length desired. There are a great many other yellow or hard pines in the market, under various trade

names, which are coarser grained, less strong and durable, and generally inferior to the long leaf variety.

White Pine. 24 lbs.; color, very light brown; grain, fine and straight; not strong, but durable, soft, and easily worked. An ideal wood for bright decks, but for this purpose should be quarter sawed and laid with the edge grain up. Owing to its close grain, easy working and staying qualities it is a favorite wood for all interior finish that is to be painted. Of late years it has become quite expensive.

White Cedar (southern). 21 lbs.; color, light yellowish brown; grain, fine and straight; not strong but tough and very durable. It is the ideal wood for planking all types of boats up to fifty feet in length, also for decks and cabin tops which are canvased. It is marketed flitch sawed, that is, with the bark on both edges, so that the builder has the benefit of the tree's shape. It can be obtained up to twenty-four feet in length, and longer if specially ordered.

Cypress. 28 lbs.; color, light to dark yellowish brown; grain, fairly fine and straight; not strong but very durable. Some is even-grained, soft and easily worked, but often it has alternate hard and soft streaks, due to hard summer wood, making it difficult to work and finish smooth. It is good for

planking and may be used for all outside finish when cheapness is desired. Interior joiner work can be made very attractive if figured grain is selected and finished bright, but owing to the difficulty of obtaining a smooth surface it is not so suitable for a paint finish. For flooring, lockers, shelves, bulkheads, and similar work it is very useful and cheaper than white pine.

Spruce. 21 lbs.; color, light yellow; grain, fairly fine and straight; not strong, but rather tough and elastic. When light construction is essential it is often used for girders, keelsons, stringers, and clamps. Light weight oars are made of it and it is a splendid material for spars of all kinds.

Hackmatack. 34 lbs.; color, light to medium dark yellowish brown; grain, fairly fine and crooked; very tough and durable. It is used only in the form of knees or crooks and is very good for the stems of small boats. These knees can be obtained from any shipyard or lumber dealer catering to boat builders and are sold by the inch thickness.

Chestnut. 28 lbs.; color, light brown; grain, coarse and straight; durable, not strong but fairly stiff; somewhat resembles oak in appearance. It is often used for deck beams and sometimes for interior finish.

Mahogany. 35 to 50 lbs.; color, light to dark reddish brown; grain, medium coarse, sometimes straight and again twisted and crossed; durable and fairly strong. There are so many varieties in the market that exact data cannot be given. Mexican mahogany is perhaps the most popular for boat work, but some other kinds are cheaper and look very well when properly finished. As mahogany shrinks and swells little it is a splendid wood for both inside and outside finish, being used more than any other material for this purpose. It is also good for planking, but expensive.

Teak. 50 lbs.; color, dark yellowish brown; grain, coarse and straight; strong and exceptionally durable. Used principally for outside finish, but sometimes for decks and planking. It swells and shrinks less than any other wood, lasts forever, and its high cost is the only reason it is not used more extensively.

White Ash. 41 lbs.; color, very light brown; grain, coarse and straight; strong and elastic; durable. Used for galley dresser tops, thwarts for small boats, and oars.

These comprise the principal woods used in boat building. There are others such as butternut, white mahogany, birch, etc., employed for

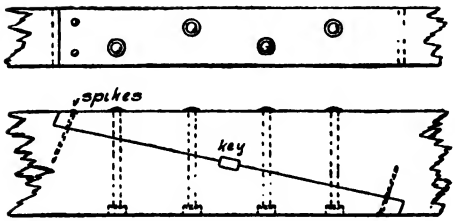
interior finish; Oregon pine for spars, decks, stringers, etc.; Spanish cedar for planking and finish, but limited space prohibits going into details.

CHAPTER III

FASTENINGS

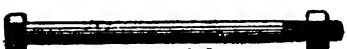
PLEASURE boats, as a rule, are of light construction and in order to make them sufficiently strong, great care must be taken in fastening the various parts. The promiscuous nailing which holds a house or box together will not answer at all and in most places bolts of different kinds and screws are substituted for nails. The kind, size, and position of each fastening must be carefully determined with a view to getting maximum strength. Galvanized iron, copper, bronze, and brass are the materials used, but never bare iron. A boat fastened with bare iron might last fairly well in fresh water but would soon go to pieces in salt water. The various kinds of fastenings used in boat construction are as follows. See page 29.

Clinch bolt. The common term for a long, through fastening having the ends riveted over washers or clinch rings. They may be of any metal, but are generally of galvanized iron or



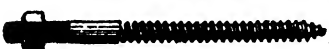
Scarph fastened with clinch bolts
Note that the bolts are staggered

Canted drift bolts



Screw bolt.
Head and nut square or hexagon

Galv boat nail



Hanger bolt

Wire nail

Carriage bolt

Wire finishing nail

Lag screw

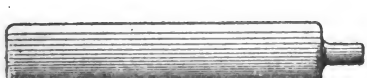
Copper cut nail

Stove bolt

Square spike

Galv boat rivet

Copper burr



Holding on iron

Clinch ring

copper and are used for fastening scarphs, stems, deadwoods, keelsons, stringers, clamps, knees, etc.

Screw Bolt. An ordinary machine bolt having a head on one end and a nut on the other. Square head and nuts are better than hexagonal, although not as neat. Very often the heads on long bolts are made by screwing on a nut and upsetting or riveting the end of the bolt a little. They may be made of any metal, but copper is too soft for the best results. They may be substituted in all cases for clinch bolts and are particularly good for engine beds, as any looseness developing can be taken up.

Carriage Bolts. A screw bolt having a round button head with a square place under, to prevent turning in the wood. They are used principally for fastening clamps, bilge stringers, etc., and are made of galvanized iron, brass, and bronze.

Drift Bolts. A bolt having a washer or clinch ring and upset head on one end only and driven like a spike. For reasons given later galvanized iron is the best material to make them of. Used in keels, deadwoods, rudders, centerboards, and similar places where there is ample wood and clinch bolts cannot be used or are unnecessary.

Material for bolts (except carriage bolts) is usually bought in long lengths and cut as required. With screw bolts ordinary washers of the

same material should be placed under both head and nut. Clinch and drift bolts should have the ends riveted or upset over washers or clinch rings. The regular clinch rings made for the purpose are best, being thicker than a washer and having a counter sink.

Beware of cast iron rings which will break at the least provocation. The kind punched from wrought iron should be used and if there is any doubt they may be tested by bending in a vise. Copper bolts are riveted over copper washers or cast bronze clinch rings made for the purpose. These should also be tested and only tough ones, that will stand bending, accepted.

Lag Screws. These are simply large wood screws with a square head. They are made of galvanized iron, bronze, and brass and are used instead of spikes or drift bolts where greater strength is required. Also used for fastening skegs, bearings, etc., but are not advised.

Hanger Bolt. A bolt having a thread, suitable for wood, at one end similar to a lag screw and a machine thread and nut at the other. They may be of galvanized iron, brass, or bronze and are used for fastening skegs, bearings, engines, etc. For these purposes they are far better than lag screws, as the part screwed in the wood need not be disturbed if it is necessary to remove the

fitting. In connection with bronze fittings, use bronze bolts only, as brass or iron will be destroyed by galvanic action.

Boat Rivets. Galvanized, button headed rivets which can be bought in sizes from $\frac{3}{16}'' \times 2\frac{1}{2}''$ up to $\frac{3}{8}'' \times 12''$ and may be riveted or used as drift bolts.

Spikes. Large nails either square or round and made of galvanized iron or cast composition. Used for fastening thick planking and other parts of heavily constructed boats. The round ones are also very handy in medium weight boats for fastening stringers and clamps where they are used in the same way as a clinch bolt.

Galvanized Boat Nails. These are rather heavy forged nails with an irregular section, tapering to a blunt chisel point. There are good and bad ones. The point of a good nail should stand bending almost double without breaking or causing the zinc coating to scale off. They are used for planking, decking, fastening frames to floors, and miscellaneous jobs. For planking, when the frames are rather small, say $1\frac{1}{4}''$ or $1\frac{1}{2}''$, the nail may be driven through with about $\frac{1}{4}''$ projection and clinched by bending the point over on the wood. However, where there is sufficient wood, they hold very well without clinching.

Galvanized Wire Nails. These are ordinary

wire nails, finishing nails and brads which have a place in joiner work, and miscellaneous unimportant parts. The large sizes make very good clinch bolts for small stringers, clamps, etc.

Copper Nails. Used in both the cut and wire variety and it is rather difficult sometimes to choose between them. The cut nail has a thicker and larger head, which is desirable, and is thicker near the head where the shearing strain between plank and frame comes, but the point is so small that a nail much too long is necessary in order to obtain proper strength. Owing to the taper, it is of course impossible to bore a hole which will allow the wood to bind equally throughout its length. A wire nail, being round and parallel, does not have this failing, but the standard size is too slim, unless an extra long nail is bought and a lot wasted. Many lengths, however, are made in two or three gauges or diameters, which gives some choice. There is no doubt that the wire nail makes the neatest job for lap streak boats and is also good for light carvel planking, while the cut nail is better for larger work.

Burrs for either kind of nail should be of a size to necessitate forcing down against the wood. For cut nails they should just slip over the point and for wire nails one size smaller than the nail will generally be found about right. Copper nails

are used for fastening planking to frames, frames to floors, the laps in clinker planking, intermediate fastenings in double planking; and the large wire nails for small clinch bolts.

Screws are of galvanized iron, brass and bronze. Galvanizing is done in two ways, i.e., dipping in melted zinc and electro plating. Dipping gives the best coating but is apt to fill the threads, while plating leaves a clean thread but is not as durable. All things considered, I think the plated screw preferable; at any rate examine them and see that the threads are good, else they will not hold. Brass screws are universally used, but bronze are better and cost little more if they can be found in stock.

For boats that are copper fastened, brass or bronze screws are used for fastening the planking to the stem and stern and to frames where keelsons, etc., prevent riveting, also for planksheers, guard mouldings, and many other parts. In fact there are few places where screws cannot be substituted for nails with better results. They are frequently used for plank fastening throughout, and make a neat job, but are not considered as good as copper nails riveted.

Regarding the comparative merits of galvanized iron and copper, there is no doubt that copper will last the longer; however, when the scantlings (sizes

of members) are sufficiently large a good grade of iron is very satisfactory and much cheaper. We might take a frame 1¼″ square as the smallest that a galvanized nail should be driven into for good results. Sometimes the large fastenings in keel, deadwood, etc., are of iron and the plank fastenings of copper, or the underwater parts fastened with copper and those above with iron. When mixed fastenings are used care should be taken that the iron and copper do not come in contact, or very near together, otherwise electrolysis will destroy the iron. For the same reason a copper washer should never be used with an iron bolt or vice versa.

Iron is stronger and stiffer than copper which permits smaller sizes, and long bolts of it may be driven tighter. The slightly rough surface caused by galvanizing holds well and if the metal corrodes slightly its grip becomes more tenacious. Unfortunately it is becoming harder all the time to obtain good iron and much of the so-called iron in the market to-day is really mild steel which, although stronger, is more subject to corrosion.

For small boats or light construction, copper, bronze, or brass only should be used. Copper, being comparatively soft, is apt to buckle if driven tight and a verdigris forms on the surface which destroys the friction between it and the wood.

For this reason all copper fastenings, whether bolts or nails, should be riveted over washers or burrs. Muntz metal, yellow metal, and tobin bronze are non-corrosive compositions, harder than copper and can therefore be driven tighter, but do not head so well. They are used mostly for screw bolts.

Practically all fastenings in boat construction require holes bored for them and it is very important that the holes are of proper size, so that the bolt, nail, or screw may be driven as tight as possible without danger of splitting the wood or injuring the fastening. For long bolts of galvanized iron or copper, a bit the same size as the bolt will be about right. Such holes are bored with a ship auger which does not cut absolutely clean, so that the hole is actually smaller than the bit and a driving fit thus obtained. Shorter bolts may be driven in holes $\frac{1}{32}''$ to $\frac{1}{16}''$ smaller. When boring a long hole it is necessary to withdraw the bit frequently to clear the chips and if there is a tendency to bind and become hot an occasional dip in grease will help.

Sometimes a long copper bolt that sticks and buckles may be driven easily if allowed to stand for a few days and any bolt will go easier if treated with grease or soap. The leading end of a clinch or drift bolt should be slightly pointed

by tapping around with a hammer to insure its following the hole and a clinch ring slipped on before driving. Usually sufficient metal is upset to form the head by the time the bolt is driven home and the head is then finished with a riveting hammer. Bolts through the keel, stem, deadwood, etc., should have the heads *countersunk* on the outside and the holes plugged with wood. It is therefore best to drive from the outside, having the bolt slightly longer than necessary; then saw it off to the neat length and rivet over a ring on the inside. If iron is being used smear thick paint over the bare metal of the head and bed the plug in white lead.

Nails can be driven in holes much smaller in proportion than those required for bolts, but great care must be taken in the case of copper that the nails do not bend in driving. Screws also must not be forced hard, or the metal will be strained even if it does not actually break. A little soap or grease on the thread will help wonderfully and should always be used for hard wood. Boat nails and square spikes must be driven so that the flat chisel points cut across the grain, because if turned the other way the point acts as a wedge, tending to split the wood.

The exposed fastenings in all first class work are countersunk and the holes plugged with wood,

the only exception being when the wood is not thick enough to permit it. The countersink should not be larger in diameter than necessary to take the head of the fastening and the depth sufficient to hold the plug. A depth of two-thirds the diameter gives good holding and about one-half the diameter is the minimum. Bore the countersink first with a Jennings, or better a Forstner bit, using a gauge of some kind to limit the depth, then follow with a twist bit or drill. Plugs for filling the countersink can be bought in any kind of wood in all required sizes. They should be dipped in thick paint or varnish, placed with the grain running in the same direction as that of the plank, and driven in with a hammer, taking care that the wood is not crushed.

One of the most important, but often slighted, operations of copper fastening is proper riveting of the nails. In the first place the nail should be driven fully in, so that it draws the parts together, and if the construction is light, a heavy iron must be held on the opposite side close to the hole. Then the burr is put on and set down hard, a helper meanwhile holding a "holding-on iron" firmly against the nail head. Next cut off the nail with nippers, leaving a projection of approximately one diameter of the nail, and form the head with numerous light blows of a small round

pene hammer and not with a few blows of a heavy one. The last two or three taps should be given with the flat face of the hammer to smooth the head. If the holding-on iron is not held firmly or the blows are too heavy there is danger of backing the nail out, and heavy blows also tend to bend the nail in the wood, greatly impairing its strength. These remarks apply to all riveted fastenings.

The size and spacing of fastenings cannot be determined by any fixed rules and the amateur must use common sense, proportioning the size to the scantling and arranging them to suit the conditions. Much information regarding the arrangement of important fastenings will be found in the construction details shown on the plates. In general, fastenings of all kinds should be staggered as much as possible so that a line of them does not cut through the same grain, which tends to split the wood. When drift bolts, nails, or screws are used the heads should always be on the thinner one of the two parts fastened; in other words, fasten the thin part to the thick part. When using drift bolts in material sufficiently wide it is good practice to cant them in opposite directions as shown on page 29 which forms a kind of dovetail greatly increasing the holding power.

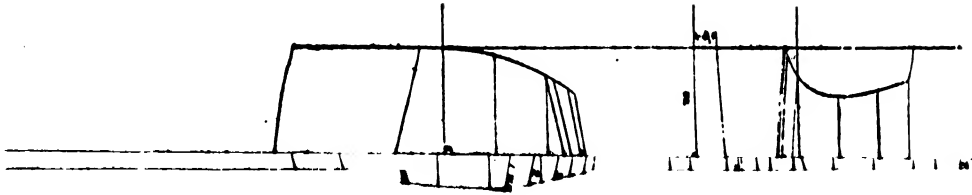
CHAPTER IV

LAYING DOWN

LAYING down is the work of enlarging to full size and fairing certain portions of the architect's drawing of the lines, so that moulds and templates can be made and from them the form of boat obtained. As the drawing is made on a reduced scale slight errors are bound to be present and the correction of these is called fairing. A line is fair when it makes a true curve, with no abrupt change, and is pleasing to the eye. To illustrate the work a 22½′ runabout is taken as an example, the lines being shown on Plate 1, and the laying down or loft work on Plate 2. For other types the details of work may require slightly different treatment, but after the amateur understands what is required he should have little trouble.

The lines comprise three plans, i.e., sheer or profile plan, half breadth plan, and body plan.

The Profile, or Sheer, Plan is a longitudinal elevation and shows the sheer of deck; the form of boat at the center line and at fixed longitudinal



sections parallel to the center line, called buttock lines; and the rabbet line; all of which appear curved. Also the base line, water lines, sections or stations, and shaft line, which are straight.

The Half Breadth Plan shows the form of deck in plan view; the form of longitudinal horizontal planes, parallel to the base, called water lines; and sections or planes at an angle, called diagonals; all of which are curved. Also the section and buttock lines which are straight. If the keel is not of uniform width, its half breadth is shown.

The Body Plan shows the form of boat at transverse vertical planes, called sections; the projected shape of stern and the deck line; all of which are curved. Also the base line, water lines, buttock lines, and diagonals which are straight.

These three plans are generally shown separately, but sometimes the body plan is drawn in the center of the profile. When laying down the half breadth and profile plans are always drawn together, which saves space and labor.

Offset Table. In connection with the lines is furnished a list of dimensions called offsets, which are distances out from the center line or up from the base line, for all points of intersection of the various fore and aft lines with the sections. In the left and right hand columns are the section numbers, so that all dimensions in the same hori-

zontal line with any section number apply to that section. The other column headings show to which particular fore and aft line the dimensions refer and are divided into two groups, viz., half breadths and heights. Each dimension is given in feet, inches, and eighths of an inch, expressed in three figures thus 3–6–5 and meaning 3′–6⅝″.

For instance if we wished to know the half breadth at deck on #3 section we would follow down the column headed DECK under HALF BREADTHS and horizontally opposite #3 section find 2–4–6. This point would then be 2′–4¾″ from the center line. Or if the height of rabbet is required on #8 section we find in the RABBET column under HEIGHTS 1–6–3 or 1′–6⅜″ which is the distance the rabbet line is above the base line. Offsets on the diagonals are given from the intersection of the diagonal with the center line. Some designers make a different arrangement of offsets, but a little study will make it clear.

There are many necessary dimensions other than those given in the table of offsets and these will be found on the plans if the designer has done his work thoroughly. Never use a scale on a blue print if it can be avoided.

Offsets are always given to the outside of the planking, but as it is the outside of the frames which concerns us principally, allowance must be

made for the plank thickness. There is a choice of two ways, i.e., take off the thickness of plank and fair the boat to the outside of frames or fair to the outside of plank and then take off the thickness of plank, on the body plan only. Although necessitating more work, the latter method is best for the amateur as the ending of the lines at bow and stern is easier. More anon.

The tools required for laying down are few and comprise rule, compasses, steel square or large wooden square, chalk line, straight edge, hammer, battens, pencils, and chalk. For drawing long lines ordinary carpenter's pencils sharpened to a chisel edge are best, or if the floor is dark colored, soapstone crayons may be used instead. A measuring rod, six to ten feet long, divided in feet, inches, and eighths is very handy, but an ordinary six-foot jointed rule will fill most amateur needs.

Battens are long straight strips of wood used for fairing and drawing curved lines, and good clear white pine is the best material to make them of. In each case the size of the batten is governed by the character of the line to be faired. It should be small enough to bend readily to the spots, yet stiff enough to obtain a true curve. A limber batten can be made to touch all the spots and the untrained eye might not see that the line is unfair, while a stiffer one will resist this and

tend to bend fair of itself. For the sheer line of most small boats a batten ½″ × 1½″ or 2″, used on its flat, will be about right; for the deck line in plan view and water lines ½″ × 1″ or 1½″ in the middle, tapered slightly at the ends to suit. If possible these battens should be three or four feet longer than the boat, but if necessary to use two lengths, have the joint near amidships where the curvature is least. A coat of black paint on these long battens make them show the lines better and is worth the trouble.

For the body plan, stem, or similar curves, they should be from ⅜″ to ½″ square at the ends and thinner in the middle where the greatest curve will be. As all of the body battens will be down at the same time, one for each section will be required and if each one is planed as needed, the size can be made to suit the requirements. See Plate 2. For holding the larger battens in place 1½″ or 2″ slim wire nails are driven through them, but the smaller ones are best held with 1″ wire brads driven on each side.

The easiest method of using the larger battens for the purpose of fairing any of the fore and aft lines is as follows: Let us assume it is the sheer line of the profile plan. Lay the batten on the floor in its approximate position, allowing at least two feet extra length at each end. Drive a nail

partly through the batten at the stem, place one end of your rule or measuring rod against the base batten, bring the sheer batten so that the lower edge is to the required offset, and drive the nail in far enough to hold. Proceed in the same way with each section or offset, then spring the free ends to continue the curve and fasten them. Now stand, first at one end and then at the other, and inspect the line carefully to see that it is fair, that is, if it forms a nice true curve throughout, without any humps or hollows. If it is not fair make such alterations as may be necessary, shifting the batten as little as possible to obtain the desired result.

Slight departure from the offsets is to be expected unless the drawing is made to a large scale and this is where judgment and a good eye come into play. After you are positive the batten is right the line may be drawn with pencil or corrected offsets taken from it as the case requires. When using the smaller battens for the body plan, stem or similar lines with quick curves, the procedure is somewhat different. First mark all the offsets on the floor and at each spot drive a small wire nail partly in; then spring the batten to these and drive enough nails on the other side of the batten to hold it in place.

A fairly smooth and even floor is required for

the work. If this will show pencil or chalk marks plainly, very good; if not it may be given a coat or two of light colored flat paint.

Near one side draw a perfectly straight line several feet longer than the boat, which will be the base line for the profile plan and also the center line for the half breadth plan. This and other long lines may be struck in with a chalk line, but a more accurate way is to stretch a fine string just clear of the floor, make pencil marks directly under it every five or six feet and draw the line from mark to mark with pencil and straight edge. Whenever a chalk line is used it should be stretched tight and snapped plumb, otherwise a curved line will result.

Now nail a straight strip of wood about $\frac{1}{2}'' \times 2''$ with its edge to the line, the strip being on the opposite side of the line from the plan. This strip, called a base batten, is not absolutely necessary but it is a great help as it enables you to place the measuring rod or rule accurately to the line without inspection, when measuring offsets. It is a good plan to start the batten a foot or so abaft the stem so that it will not interfere later with the water line battens. If only one boat is to be laid down a simpler way is to drive a wire nail, with its upper side to the base line, at each section, which answers the same purpose.

Set off along the base line the positions of the sections and at these points draw lines perpendicular to the base, extending them beyond the highest point of the sheer or greatest half beam and number each distinctly. Above the base and parallel to it draw several feet, at each end, of all the water lines in the profile plan. Offsets are generally given on these lines, from a perpendicular, for the shape of stem and they are also necessary to obtain the forward endings of the water lines in the half breadth plan. At the stern these water lines should be extended several feet and will be used for expanding the transom.

Short lengths of the buttock lines in the half breadth plan may also be drawn, but as these might cause confusion for the amateur, they can be omitted at this time. They are used to obtain an ending for the buttocks in the sheer plan. The floor is now prepared and you are ready to draw the lines proper.

Profile. If the bottom of keel is straight, or straight for part of its length, you will find dimensions giving the heights for the ends of the straight part. Set these off above the base and draw the line, extending it well forward so that the outline of stem can be drawn to meet it nicely. If the bottom of keel is curved draw the line with a suitable batten. Next fair and draw in the

outline of bow, working from dimensions given on the plans. Also draw the outline of stern and after end of deadwood, using straight edge or battens as the case requires.

The after end of deadwood, where the shaft passes through, must be square to the shaft line, which line should also be drawn at this time. Then fair and draw the rabbet line on keel and deadwood, but not on the stem. The rabbet line on stem, the after side of stem, and top of keel are generally determined later, although for some types these dimensions are fixed by the designer.

The lines or construction plans should show the arrangement of wood for the shaft log, deadwood, stern post, stern framing, etc., and the outlines of these parts should be drawn, either to given dimensions or to suit the conditions and material available. Next fair the sheer line of deck. Although not absolutely necessary, it is advisable to draw it in. Before taking up the batten for this line take a small stick, of any convenient size, and using it in the same manner as the measuring rod, mark on it the corrected heights at stem, stern, and at each section, carefully numbering each one. This operation is called "picking up" and the stick a "pick up rod" or "batten" which should be put away for the present.

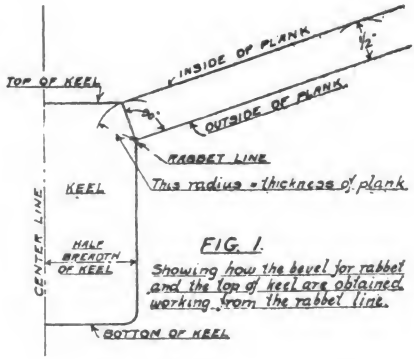


FIG. 1.

Showing how the bevel for rabbet and the top of keel are obtained working from the rabbet line.

Note that the intersection of each water line with the half breadth of stem in the half breadth plan squared up to the corresponding line in the profile plan, gives a point for the rabbet line.

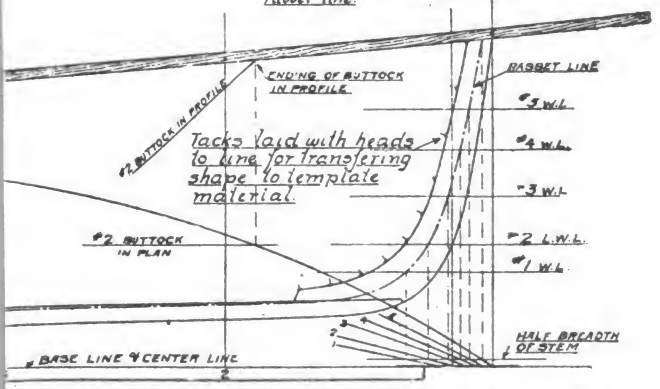
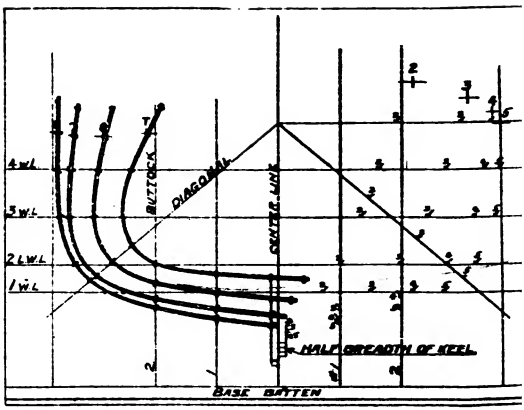
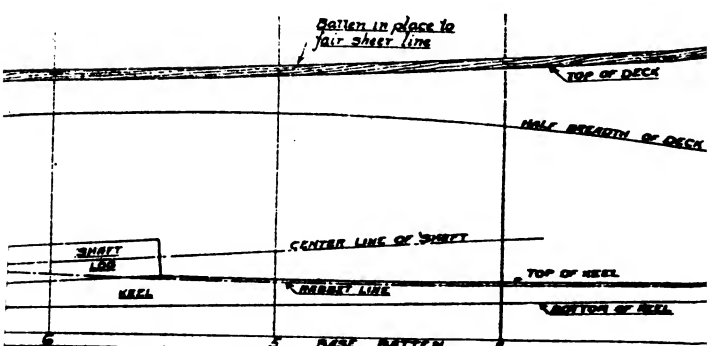


PLATE 2



BODY PLAN ON PORTABLE BOARD FIG.

In the fore body the offsets are all spotted ready for the battens. In the after body the battens are in plac Note the extra length of battens where possible to obtain a good ending



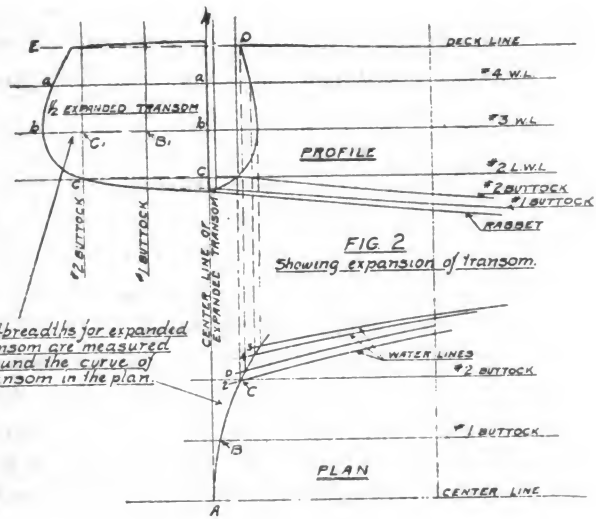
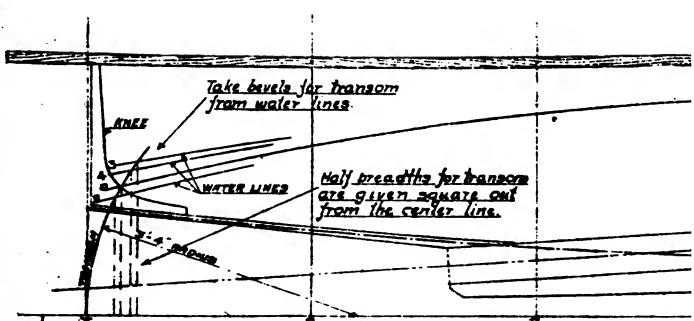


FIG. 2
Showing expansion of transom.



Half Breadth. In the half breadth plan the deck line must be faired, drawn, and the corrected half breadths picked up on another rod. A line representing the half breadth of stem should be drawn, also the half breadth of keel if it is not parallel, which is frequently the case in sail boats but seldom in launches. This finishes the profile and half breadth plans for the present.

Body Plan. For this plan I would suggest a portable drawing board made of several boards secured with cleats on the back, which can be placed on horses, or moved about at will, which greatly facilitates the work. Close to the lower edge nail a straight strip of wood, about $\frac{1}{2}'' \times 2''$, to form a base line and perpendicular to this draw the center line. Then working from dimensions given on the plans, or in the offset table, draw the water lines, buttocks, and diagonals with straight edge and pencil. See Fig. 3, Plate 2.

Tack a straight batten temporarily with one edge to the center line and with rule placed against it, or the base batten, as the case may be, spot the half breadths and heights on all the lines marking each one thus $\sqrt[3]{}$ with its section number. As the half breadths and heights of deck and the heights of rabbet have been faired, these offsets must be taken from the "pick up rods" and not from the offset table.

For the deck draw short horizontal lines at the proper heights and spot the half breadths on them. Draw a line for the half breadth of keel and on this spot the rabbet heights, which should be picked up from the sheer plan. Spot all the offsets on one side first, then shift the center batten to the opposite side of the center line and do the other side. It will be found convenient to mark all sections on one line without shifting the rule, rather than one section at a time on all the lines.

Drive small nails at all the spots and bend a batten for each section, allowing it to extend six inches or more above the sheer to insure a fair ending. If the rabbet heights are so close together that the battens interfere they may lap over each other or be tapered as seems best. When all the battens are placed, inspect them carefully and make such changes as will make fair lines, but on no account change the deck or rabbet lines as these are now fixed. Fair the battens with as little alteration as possible, giving and taking a little here and there as judgment dictates, keeping in mind that offsets on lines which cross the sections nearest at right angles are the most reliable. It may be that a few extra nails intelligently placed will help. Sometimes the spots on one line, a diagonal for instance, will seem to be out on all the sections and may safely

be disregarded and those spots held to which give the fairest lines. This first adjustment of the body battens is very important and if well done saves much trouble later on.

When the battens are arranged to your satisfaction the real work of fairing begins. Take a diagonal through the bilge first; from the body plan, pick up the offsets on a rod, and run a batten to them in the half breadth plan. If it is not fair it must be made so and the body battens altered to suit. If they have been shifted on this diagonal try putting them back, making them fair again by shifting some other points. In the same manner test all the other fore and aft lines, working back and forth from one plan to another until all three plans agree and show continuity of form and fairness.

As previously mentioned, lines which cross the sections nearest at right angles are the best fairing lines. In the lower part of the after body where the bottom is rather flat, the buttocks are good, but further forward where there is considerable deadrise the water lines are better. For the same reason water lines are good in the top sides but of little value in the bottom, especially aft. Diagonals if well placed are always reliable the full length and should be faired first. It may not be necessary to run all the fore and aft lines

shown on the drawing and if the first three or four are wisely chosen there should be little trouble with the remaining ones.

Ending a Water Line. To find the forward ending of a water line in the half breadth plan square down from the profile the point where the water line cuts the forward side of stem and set out the half breadth of its forward edge, in this case ¼″. The after ending for a canoe stern would be found in the same manner. For the boat under consideration, an arc of a circle, representing the deck line of stern should be drawn with large trammels, a piece of string, or a stick and a nail and the half breadth spotted on it square out from the center line.

Ending a Diagonal. A diagonal is ended in the same way, except that the half breadth of stem is measured on the run of the diagonal and the point where it cuts the stem must be transferred from the body to the sheer and then squared down to the half breadth plan.

Ending a Buttock. To end a buttock in the sheer plan a short section must first be drawn in the half breadth plan where it crosses the deck line and this point squared up to the sheer line. Plate 2.

A foot or so of each water line should be drawn at the bow, in the half breadth plan, so that the

bearding of stem and the rabbet line may be obtained; also a short length of the water lines and buttocks at the after end, to give bevels for the stern. There is no need to draw any other fore and aft lines.

When satisfied that the body plan is fair, draw in the sections and take up the battens. Now take a pair of pencil compasses, opened to the thickness of plank, and every six inches or so strike in little arcs as shown on Fig. 1, Plate 2, and through these draw lines representing the inside of plank or the outside of frame. From the rabbet line at each section in the body plan, draw a short line square to the plank until it intersects the inside of plank. See Fig. 1, Plate 2. This line gives the bevel of keel forming the rabbet and the points of intersection give heights for the top of keel, which should be drawn. Transfer these heights to the sheer plan and draw a line for the top of keel.

Stem. Square up from the half breadth plan to the sheer plan the point where each water line and deck line cuts the half breadth of stem and draw a line through the spots, continuing the lower part into the rabbet on the keel. This is a line which gives the bevel of the stem and in nearly every case is also the rabbet line. Next draw the after side of stem as shown on the plans,

or if it is not shown allow enough wood abaft the rabbet to give sufficient strength and good landing for the plank ends. If the stem is to be made of a crook, this line should be continued aft to form a good lap on the keel, or if it is to be of straight stuff and connected to the keel with a knee, the knee should be drawn. Also draw the knee connecting the keel and transom or stern.

Expanding the Transom. On the body plan is shown the projected form of stern or transom; in other words, the form as seen when viewed from directly aft. As this stern is curved it is evident that the true form is somewhat larger than shown, and this expanded form must be obtained. The method of doing this is shown in Fig. 2, Plate 2. In practice this work would be performed on the profile plan, but is shown separately to avoid confusion.

From point D (the height of deck at stern) draw a horizontal line D E, also extend the water lines as shown if not already done. On the plan, place the end of a thin batten on the center line at A, bend it around the curve of stern, and mark on it the points where the buttocks, water lines, and deck line cross. Now with the end of this batten on the center line A A spot the true half breadth of the deck A E and water lines a a, b b, and c c.

On any level line, say #3 water line, spot the buttocks at B and C and draw them vertically. The body plan shows these buttocks 9″ and 18″ from the center line but it will be seen that they are somewhat more than this now, owing to the greater distance around the curve of stern. Pick up the buttock heights from the body plan and spot them on the lines just drawn.

We now have a series of spots, i. e., rabbet, buttocks, water lines, and deck through which a line may be drawn giving the expanded or true shape of the transom. It may be that the lines given on the drawing do not give sufficient spots to draw the line properly, and if such is the case extra water lines and buttocks may be drawn, on the full sized body plan, and the points transferred in the manner described for the regular lines. A line showing the desired crown of deck is next drawn which completes the job.

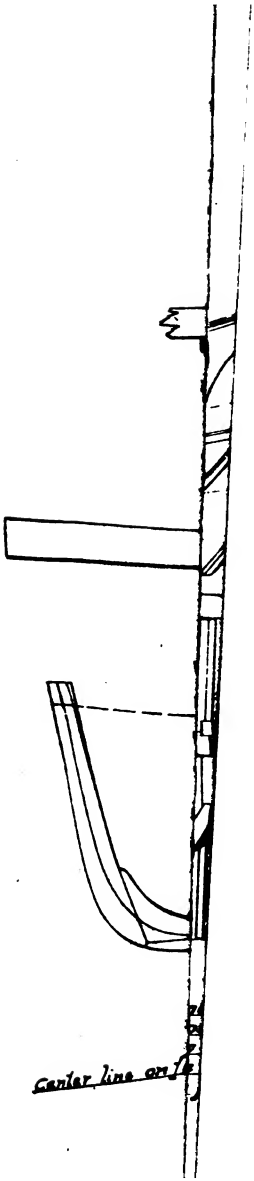
In order to save labor it is a good idea to make this expanded drawing on a piece of heavy paper, which can be cut out and used for a pattern, instead of drawing on the floor and making a wood template. If this stern had a rake, it would be necessary to spread the water lines to the distance apart on the raked line, in the same manner the buttocks were spread to take into account the greater length on the curved stern,

and the expanded stern would be drawn using the raked line as a center line. While the principles explained apply to any type of stern, the practical application may require modification to suit other forms.

TEMPLATES AND MOULDS

We now have the outlines of keel, stem, and other members forming the backbone of the boat, drawn full size, and for various reasons it is advisable to make templates or patterns for each part. It is an easy matter to shift these templates about on the material to be used and so cut it to the best advantage, avoiding knots and other imperfections, also in many cases the amateur can save himself considerable hard work by taking the templates to a mill and have them get the stuff out in the rough.

These templates may be made of any soft wood ¼″ to ⅜″ thick. There are numerous methods employed in boat shops and mould lofts for transferring the lines from the floor to the material, however, when only one boat is to be built, it does not pay to make special appliances and about the simplest way is with tacks or small wire nails. Lay these with their heads to the lines bounding the part to be taken off, spacing them to suit the character of line. See Plate 2 where they are


Center line on fl

shown arranged on inside of stem. For instance a long, easy curve such as a keel may only require them 10″ to 15″ apart while around the stem where the curve is sharp it may be necessary to have them as close as 2″ or 3″. Lay a board from which the pattern is to be made carefully on the tacks and press firmly to imbed the heads in it, then turn it over and with straight edge or battens draw through the spots obtained. Saw out and plane the edges so that it fits the lines exactly, then tack it in its proper place on the floor. Treat each part in the same way so that the whole backbone is represented in the thin pattern stuff.

Also make a half template for the transom if it was not expanded on paper as previously mentioned. While the templates are in place mark across them the positions of the sections, frame stations, water lines, deck line, center of rudder port, center board trunk, and any other information thought necessary.

If the material is not wide enough for any part, such as the stem, the template may be made of several pieces, butting the joints and securing them with cleats or butt blocks which should be of ample size and well fastened. If the keel is long and straight, a complete template is not absolutely necessary, but patterns should be made of

the ends where it joins or scarphs to other parts. The shaft log also, being usually of parallel width, may be omitted, however, it is very much better and safer to make the backbone complete.

Moulds. The moulds are temporary forms,

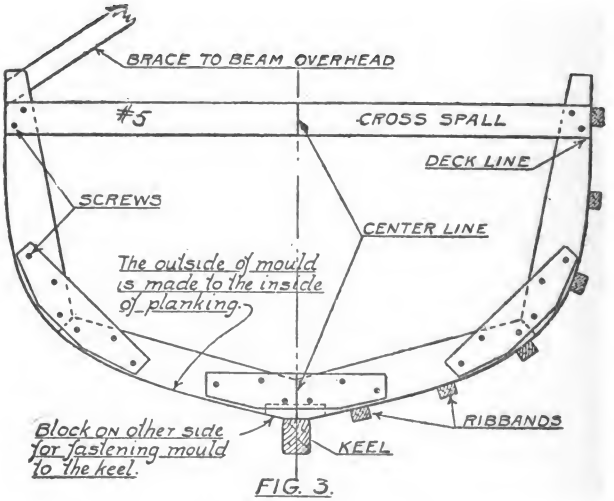


FIG. 3.
MOULD CONSTRUCTION.

made to the inside of plank, which determine the shape of the boat, and are built of any soft wood ¾″ or more in thickness. One complete mould (both sides of boat) must be made for each section. Fig. 3 shows the usual construction. The lines may be transferred from the body plan with tacks as described for templates or by the follow-

ing method. Bend a thin batten about ¾″ wide with its outside to the line, holding it in place with wire brads, driving as few as possible on the outside and with all nail heads below the top edge. Then lay a board in the best position on this and with a pointed rod, turned up at the end, reach under and scribe along the batten. Cut out and plane to fit the line, also fit to top of keel and to center line. The upper end should extend 6″ or more above the deck line. When the pieces forming one side are fitted mark out a duplicate set for the other side, then tack the original set in position on the body plan and secure the joint with a butt block, screw fastened; also plainly mark on the side and edge the sheer height and water line. Now turn this half over and using it as a pattern, fit and fasten its mate together, which brings the butt block on the opposite side as it should be. Next place both halves in position and fasten the cross spall and cleat connecting the heels, and mark the center line on them. The position of the cross spall is immaterial, although it is generally placed at the deck line, but it should be level. Sometimes instead of having it at the deck line it is placed at a uniform height from the base.

A string stretched from stem to stern can then be kept close to the center marks, which is a guide

in setting the moulds plumb and a continual check on the trueness of the boat as the work progresses. It is sometimes necessary to have more than one cross spall and diagonal braces as well, but one is usually sufficient for small boats if the mould is strongly built. If it is intended to build upside down the moulds should be continued above the deck to a level line drawn a little above the stem head. See Fig. 1, Plate 3.

When a keel batten is used as in Fig. 3, Plate 5, or if the inside of plank is below the top of keel, as in Fig. 3, Plate 4, the mould must be notched to fit over the batten or keel. The same applies in way of shaft logs as shown in Fig. 2, Plate 3, where the mould is cut off entirely and connected across the top of shaft log. In any case the mould must be made and fitted so that its outside represents the inside of plank.

CHAPTER V

THE BACKBONE

THE stem, keel, shaft log, deadwood, and stern framing form virtually the backbone of a boat and are the foundation upon which the hull is built. Each distinct type requires different treatment, at the same time there may be several ways of accomplishing the same result, so that designers either follow pet ideas or are governed by cost or other considerations. There are innumerable combinations, but the examples shown will give a general idea of the work.

Fig. 1, Plate 4, shows a construction suitable for medium or large cruisers, having a center keelson and sections aft with a reverse curve. A scarph is shown in the keel, which may be made if necessary, but seldom will an amateur attempt a boat so large that material for a keel cannot be obtained in one piece. When a center keelson is used it is almost imperative that the floors be made of natural crooks. If they are made of straight grained stuff it is necessary to have them

deep to avoid cross grain, and this brings the keelson too high. In connection with a center keelson, blocks are often fitted between the frames, filling the space between keel and keelson and projecting beyond the side of keel, thus forming a back rabbet for the garboard strake. Fig. 1-A, Plate 4.

Fig. 2, Plate 4, shows a somewhat similar arrangement without keelson and suitable for a boat having no reverse in the after sections. For boats of the same size this construction requires a larger keel, as there is no keelson, but the floors being deeper, that straight grained lumber may be used, need not be so thick. If the cabin floor is not too high it is a good plan to fix the height of the floors so that they also form the cabin floor beams.

Fig. 1, Plate 5, shows a construction suitable for runabout types and is the same boat as the example given for laying down. It will be noted that the portion of keel abaft the shaft log is very light, but the required strength in this case is obtained with two deep side keelsons, which extend nearly full length of the boat. The engine beds are bolted to the sides of these and they also take the bolts holding the shaft strut which makes a strong combination.

Fig. 2, Plate 5, shows a typical speed boat

type of keel which is on its flat instead of having its greatest dimension vertical. This type is usually rabbeted so that a backing is formed for the garboard strake and is also made wide enough in way of the shaft to allow the shaft log to be bolted to it on the inside. Such a shaft log may be of wood or cast bronze, the latter type being a commercial article. If desired a deadwood may be bolted on the outside.

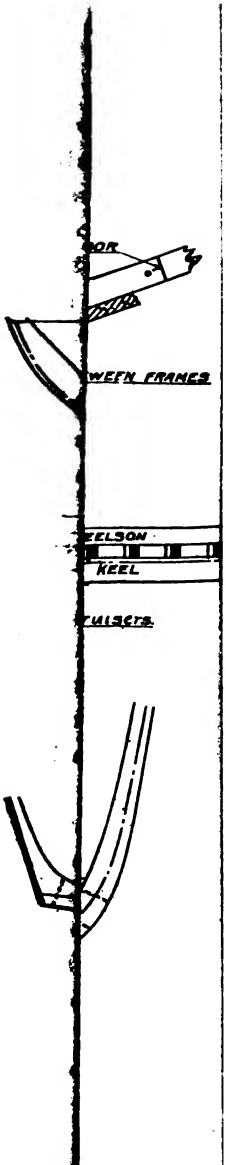
Fig. 3, Plate 5, shows the keel for a round bottomed row boat which is cut from a plank and a batten fitted on top. This is fastened to the keel with screws, rivets, or nails and the garboard plank riveted to it as shown. Plate 6 shows a keel construction for a centerboard cat boat also one for a keel racing sloop.

Keels. When getting out a keel such as is shown on Plates 4 and 5 first plane the material to the proper thickness, then apply the template and make the keel exactly like it, taking care that all surfaces are planed square and true. Mark on it plainly the positions of the sections and frames. Next cut the rabbet. In most cases of launch construction this is simply a chamfer on the upper corners of the keel so that the edge of the garboard strake fits square against it. Fig. 1, Plate 2. Take bevels from the body plan and, with a chisel or drawknife, chamfer a short place

at each section, then with these points as guides, chamfer the whole length with the angle changing uniformly from point to point. A professional does this by inspection, but it is safer for the amateur to draw a line on both top and side of keel with a batten. If the rabbet is as shown in Fig. 3, Plate 4, make a little template of thin wood or cardboard for each section as a guide.

The keels shown on Plate 6 require slightly different treatment and are more difficult as no two sides are parallel. In these cases the keel should first be cut out in accordance with the template, the top and bottom planed true, and the sections marked thereon. Next draw a center line on both top and bottom and at each section set off the widths as shown in the full size half breadth or body plans. Draw fair lines through these points and cut the keel to them. Get out the deadwoods and other parts in the same way, leaving them rough and a little large, then after they are all bolted together finish all over and cut the rabbet, working from a fair line drawn with a batten and templates made to the body plan sections.

For a centerboard boat the slot is now cut, and the trunk logs bolted fast. The slot must be very carefully laid out on both top and bottom of keel. The easiest way to cut it, is to first bore


WEEN FRAMES
KEEL

a few holes at one end and with a chisel clean out a place large enough to start a rip saw, then saw down each side, working alternately from top and bottom to insure a true cut.

Stems. Plates 4, 5, and 6 show a variety of stem constructions. For example, let us take the runabout stem which we will assume is to be made of a hackmatack knee. First plane the knee to the proper thickness, then cut it out and plane the edges to the exact shape of the template. Leave considerable extra length above the deck as it will be found very convenient to nail stay laths to when setting up. On the forward edge draw a center line full length and on each side of this a line for the half breadth, at its forward edge, in this case ¼″. At the lower part of stem beginning, say at #1 water line, these lines should gradually spread apart so that they will fair into the half breadth of keel.

On the sides draw the water lines, deck line, and rabbet line. Points for the rabbet line may be spotted on the water lines, taking them from the full size sheer drawing, or if the rabbet line has been put on the stem template, it may be transferred to the stem by pricking through the template with an awl, thus getting a series of spots through which the line is drawn. Now fit the stem to the keel, taking care that a good tight

joint is made and that the rake of stem is right.

Note in the drawing that the keel does not extend forward to a sharp edge, called a "shim

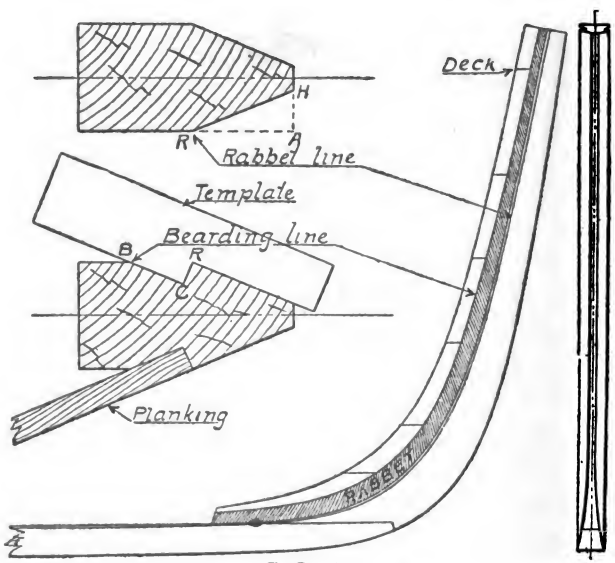


FIG. 4
CUTTING RABBET IN STEM.

edge," but is cut so that the end is an inch or so wide. The blunt end is called a "nib" and should always be made in such places. The stem may now be placed on the bench or horses, worked into shape, and rabbeted. See Fig. 4.

In this case the side of stem finishes out in line with the planking, so the proper shape forward

of the rabbet line is obtained by cutting from the rabbet line to the half breadth line on the forward edge, thus removing the wood shown by the triangle R A H. Next make a template of thin wood as shown, with the shoulder R C square and equal to the thickness of planking and with this to guide you cut the rabbet R C B. Another way is to obtain and draw a bearding line and work from this using as a template a piece of wood the same thickness as the planking. This bearding line is where the inside of plank cuts the side of stem and is obtained from the full size half breadth plan in the same manner as the rabbet line. Do not start to cut at one end and finish as you go, but cut notches about six inches apart, then connect the notches and finish all fair and smooth.

It is better not to finish the lower part of the stem until it has been bolted to the keel when a batten should be used to connect the rabbets on stem and keel, the half breadth of forward side of stem to the half breadth of keel and the whole finished in fair lines. It is always wise for the novice to leave the rabbet rather shallow, especially around the forefoot, and trim it out later as each plank is fitted. The stem may now be permanently bolted to the keel, finished, and fitted with a stop water. A stop water is simply a

dowel of soft wood ¼″ to ½″ in diameter, extending from side to side through a jont, where it crosses the rabbet. Its function is to prevent any water finding a way through the joint between stem and keel.

It is customary to fix the rabbet line at the line where the side of stem is cut by the outside of plank, as described in the chapter on laying down and illustrated in Fig. 4. This gives the maximum thickness of wood between the planks of both sides; however, if the boat is very full bowed this position may not give sufficient landing for the plank ends. Referring to Fig. 4 it is quite evident that after the stem is shaped as shown in the upper section, the rabbet line may be drawn nearer the forward edge, thus increasing the distance B C, but in no case should the wood between the planks be less than twice the thickness of planking.

For stems built up of two or more pieces, the various parts should be planed to the proper thickness and permanently bolted together before any other work is done. Sometimes the side of stem forward of the rabbet does not follow the same angle as the plank. This is frequently the case in very full bowed boats. In a case of this kind a bearding line *must* be drawn on the stem to cut the rabbet to. Other stems have the for-

ward edge gradually increasing in breadth from the water line up which makes a very neat bow; and sail boats with bowsprits often have the stem square for some distance down as shown on Plate 6. Each case must have slightly different treatment, but the problem usually works out easily once the principle is understood.

Shaft Logs are made in several different ways. Some are of one piece of wood with the hole bored out, but this frequently requires special tools and if the log is long the job often ends in failure. Others are built up of two pieces, bolted together side by side, with half the hole cut out of each, and others again of two pieces bolted together one on top of the other. The latter method is best. Shaft holes are often fitted with a lead or copper sleeve which is flanged and fastened to the log at both ends or screwed into the stuffing box and stern bearing; however, it is not necessary for small boats.

For a shaft log select perfectly sound oak and plane the pieces straight and square, then cut half the shaft hole from each piece, roughing with a gouge chisel and finishing with a round plane. Cut grooves for the tongues with a plow plane if machinery is not available. It is very important that these grooves, also the shaft hole segments, register exactly and to insure this, gauge lines for

the sides of the hole, and plow the grooves from the same side of the logs. For the grooves first plow one on each piece then change the gauge on the plane and cut the other two. Tongues for a light runabout should be about ¼″ × ½″, larger boats in proportion up to about ½″ × 1″.

Generally it will only be necessary to hold the log together with a few fastenings as the through fastenings put in later will give ample strength. As a rule it is necessary to make the shaft log of greater thickness than the keel and deadwood and the portion which projects outside the planking should be rounded off as shown in the sections on Plates 4 and 5.

Stern Framing. This portion of the backbone varies in construction more than any other part but the arrangement is generally shown on the plans. Fig. 2, Plate 4, shows a very simple arrangement. In this case the keel forms the deadwood below the shaft log and the horn timber the deadwood above. The transom is connected to the horn timber with a natural crook knee of oak or hackmatack to which it is fastened with screws. The stern post has a tenon into the horn timber and is notched into the keel. This connection between stern post and keel is often reinforced with brass dovetail plates let in flush on both sides and

through riveted. The stern post can be omitted altogether, but does not make a first class job, one objection being that the stern bearing bolts would be in "end wood" where the holding is poor.

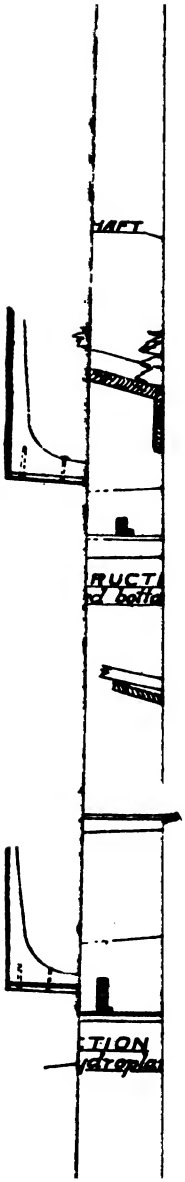
Fig. 1, Plate 4, shows a more complicated arrangement with more parts and a different type of stern. The overhanging portion is shaped and rabbeted in the same manner as a stem, getting the form for the upper portion from the water lines and the lower part from transverse sections. No doubt the plans will show a section at the end of the water line, but it may be necessary to draw in one or two extra ones. Cutting the rabbet is more difficult when there is a reverse curve in the sections as shown in Fig. 1-B, Plate 4, and it is a wise precaution to draw an extra section or two in the body plan and make templates from them, then draw a bearding line and work from that.

In any case plane the material to the proper thickness and shape each part in accordance with the templates, taking great care to plane the surfaces straight and square, then bolt them together with the shaft log and keel. Next cut the rabbet, fit stop waters in all joints and finish the whole fair and smooth. The keel and stern post should

be tapered above and below the shaft hole as shown in Fig. 1, Plate 4, which makes a neat finish and a clean run for the water.

In general all joints of the backbone should be well fitted and liberally coated with thick paint before bolting together. Use screw bolts or clinch bolts as much as possible and have the parts securely clamped together when boring the holes. For a large boat it may be difficult to get bolts through all the parts of the deadwood in one length and they will need to be fastened together in sections. Fig. 1, Plate 4, shows a case of this kind, with the keel, deadwood, and shaft log clinch bolted together and the horn timber drift bolted to them, but other combinations may be advisable. Extra long bolt holes can be managed by boring all the holes as far as possible, then take off the top member or two and finish. In this way a bolt may be made to take a slightly curved course, to clear the shaft hole when the keel is narrow, but as a rule the holes should be as straight as possible.

Lay out all the fastenings carefully so that they will not interfere with stop waters, floor fastenings, rudder port, etc. Where possible countersink all fastenings outside and plug with wood, but if the material is too thin for a counterbore, let them in flush and putty. When the backbone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is finished and smoothed up give it a coat of thin lead paint or varnish all over, and if time permits give the bottom of keel one or two coats of copper paint in addition, which will save considerable trouble later.

Centerboard Trunks. Strictly speaking a centerboard trunk does not form a part of the backbone, but as it is closely related thereto and as this is the best time to build it I will include it under this head. Refer to Plate 6. The posts at each end are made of oak or other strong wood and make a neat, tight fit in the slot, through which they extend to the bottom of the keel. The trunk logs, also of oak, are quite heavy and fastened to the keel with through bolts, either riveted or set up with nuts. The joint between them and the keel is best made watertight with a soft wood tongue as shown, but sometimes a strip of felt well coated with white lead is laid between and squeezed tight with the bolts.

Above the logs the trunk is built up of thinner material, ⅞″ or more in thickness, with tongues in the seams and each strake drift bolted to the one below it. The material should be the same as the interior finish. At the ends both logs and thin planking are well fastened to the posts with through rivets or screws and the joint made watertight with a couple of strands of candle

wick or a tongue. When the trunk extends under the forward deck the post should be carried up and securely fastened to the deck.

Transoms are built up of as few pieces as possible to obtain the necessary width. If the material is sufficiently thick the joints may be fitted with tongues or dowels, but a better way is to fasten a seam batten on the inside with screws or rivets. First fit and fasten the pieces together approximately the proper size and form, then mark out the exact shape from the template. This gives the shape of the after side, but when sawing out leave some wood so that the proper bevel may be made when planing the edges.

The simplest way is to make the transom to the inside of the planking which laps over and finishes flush with the after side, but the neatest and best way is to make the transom to the outside of planking and rabbet the edge, so that it shows a margin of ¼″ to ⅜″ all around. See Fig. 5. In either case a good substantial nailing piece should be fitted around the edge to take the fastenings in the plank ends. The fastenings in this piece may be screws or rivets, but have plenty of them as it is a weak place in every boat.

The bevels for the upper part are taken from the water lines in the half breadth plan and for the bottom from the buttocks in the sheer plan,

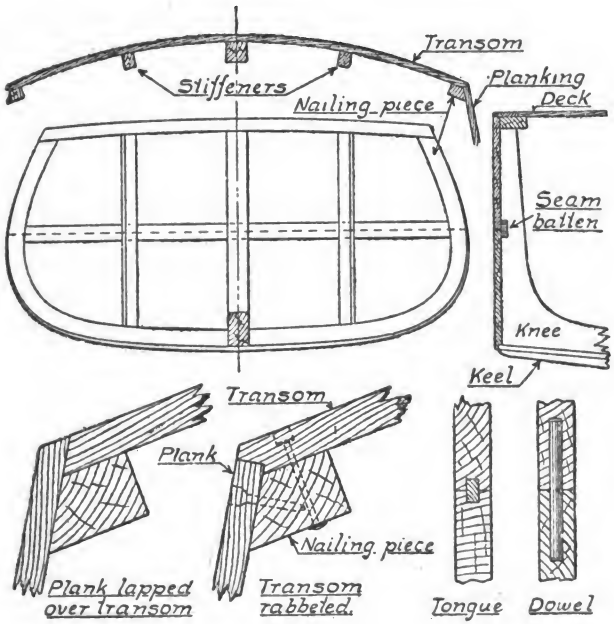


FIG. 5.
CONSTRUCTION OF TRANSOM.

which lines were drawn for this purpose when the boat was laid down. Between this reinforcement and the knee connecting the transom to the keel, should be fitted one or more vertical stiffeners well fastened. These may be cut out to go over the seam battens or the seam battens cut.

If the transom is curved the boards must be steamed and bent over a form before being fitted

together. Make the form with considerable more curve than the finished transom, as the boards will flatten out of themselves when taken off the form, and can be forced flatter if required, to get the proper curve.

Transoms for row boats are made thick enough (1″ or more) so that the planking, which is usually thin, may be fastened to it directly and the reinforcing piece omitted. The seam battens and stiffeners are also left off and if a joint is necessary a tongue and dowels are fitted. Some types of sail boats have very small transoms which are often worked out of a solid piece of wood.

CHAPTER VI

SETTING UP

SETTING up is the work of laying the keel, erecting the moulds, and running the ribbands. There are several ways of going about it depending on the type of boat and the conditions under which she must be built.

Taking into consideration first the type of boat; a flat bottomed row boat or a lapstrake boat with bent frames is easiest to build bottom up. Such boats are planked first directly on the moulds and the upside down position makes planking easy, after which they are turned over, the frames fitted, and the other work completed. Second, boats that are carvel planked and require to be framed first, are best built right side up and many professionals build all types and sizes in this position.

Next, considering conditions, there is no question but that the ideal place is indoors, with a good solid floor and means of bracing the moulds, stem and stern, over head. Few amateurs have

such a place available and must make the best of an outdoor position so that both conditions will be dealt with.

First let us consider a small lapstrake boat to be built upside down, indoors, and refer to Fig. 1, Plate 3. Draw a center line on the floor and the section lines square across it. Set up the moulds with their face sides (the side without cleats) to the section lines, the moulds forward of amidships being abaft the lines and those abaft amidships forward of the lines. Due to the shape of the boat the planking will only touch on one corner of the moulds and placing them in this way brings this corner at the section as it should be. Hold a plumb line to the center lines marked on the moulds and set them plumb with their centers directly over the center line on the floor. Secure them to the floor with cleats and brace them plumb in a fore and aft position. Use screws in the cleats so that the structure will not be racked when these fastenings are removed to turn the boat over.

As previously mentioned when a boat is to be built this way the moulds should all be carried up to a common level line above the deck so it is a great help if the floor is level. Should it be irregular the ends of the moulds will need some trimming or shims (thin pieces of wood) placed

under them. The form and fairness of the boat depends on the accuracy with which the moulds are placed so be very particular to have them centered exactly, plumb in all directions, and well braced.

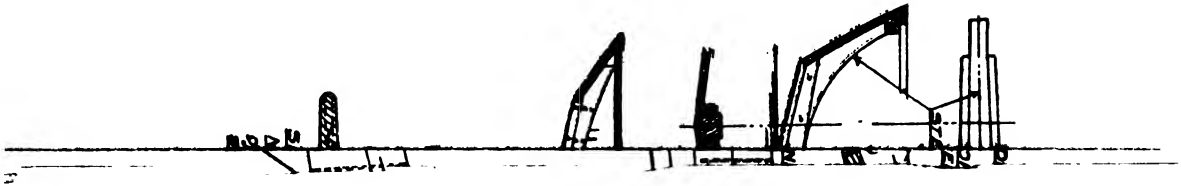
Next place the keel, with stem and transom attached, in position and fasten it to the moulds with screws through blocks fitted on them for that purpose. If the work so far has been carefully done the moulds should all register with the section marks on the keel, but if they do not, something is wrong and should be corrected before proceeding. Secure the stem head to the floor with cleats around it also with one or two nails "toed" through it into the floor. Brace the transom rigidly, being sure that it is square across and has the proper rake. Now take a batten about $\frac{3}{8}'' \times 2''$ somewhat longer than the boat and, with some one to help, bend it over the moulds in various places to test the fairness.

When lying in the stem rabbet and against all the moulds it should give a fair fore and aft line anywhere from keel to gunwale and if it does not, test the suspicious moulds to see if they are out of position. Should a mould correctly placed be full or slack and show the same discrepancy on both sides, trim off a little or shim out as required until the batten shows fair. When satisfied that the

moulds are right, fasten a fairly stiff batten midway between keel and gunwale which helps hold the moulds in place and adds rigidity to the whole form. The boat is now ready to plank.

If this type of boat is built outdoors, planks may be laid on the ground, leveled, and the moulds erected on them as described or the moulds can be set up on two substantial fore and aft timbers to which the cross spalls are fastened. In this case the cross spalls must be fastened to the moulds at the same height and the moulds need only extend a little above the sheer line instead of to a common level line.

Let us next take the case of a carvel planked boat to be built right side up, indoors. Fig. 2, Plate 3. Draw a center line and mark the sections or mould positions on it, then at each section erect a post, nailing them to the floor and bracing as shown. These posts should be high enough so that work on the bottom, such as boring for plank fastenings, riveting floor fastenings on the under side of the keel, etc., can be done properly and in comfort. Have the posts a little longer than necessary and after they are all in place, stretch a string to the proper rake of keel and saw them off. If the bottom of keel is curved, the heights of the posts may be marked from the keel template, if one was made, or the heights set



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up from a base line, which may be marked on the posts from a tightly stretched string.

The size of posts will depend somewhat on the size of boat but 2″ × 4″ studding is a convenient sized material and will answer in the majority of cases. When locating the center line, due regard should be given the bracing of the moulds, for if they can be braced from above the work is much simplified, as there is then nothing in the way, on the outside, to interfere with the work of planking. A beam of some kind running fore and aft directly over the center line is the best and should be arranged if possible.

When the posts are ready lay the keel on them in its proper position and secure it to the posts with cleats, screw fastened on the side. At each section fit a post, perfectly plumb, between the top of keel and the overhead beam, so that the posts forward of amidships have their after sides to the section marks and those aft their forward sides to the marks. Set up the moulds perfectly plumb and fasten them with their face sides (the sides without cleats) to the posts. Next brace the moulds securely so that they are square across the keel, also brace the stem head and transom or stern frame. With a suitable batten test the moulds to see that everything is fair and if so, we are ready to put on the ribbands.

If a building is not available, heavy cross ties should be laid on the ground, one at each section, and the proper height for the keel built up with blocks or posts, although the latter are rather difficult to hold with no rigid floor to brace to. Nail the blocks together or, better, secure them with a cleat. The cross ties must extend at least a foot beyond the boat on both sides so that " shores " or braces may be footed on them to hold the moulds, also the hull when in frame and after she is planked. The moulds are secured to the keel with blocks and braced down to the cross ties as shown in Fig. 3, Plate 3.

When fitting these shores keep them in line as much as possible so that they will not interfere with the ribbands. When it is time to remove the moulds, these shores must be transferred to the nearest frame, and again shifted to make way for the planking in the bilge. At this time the upper strakes are usually on and the shores are fitted under a block screwed fast to the planking. The greatest care must be taken at all times to keep the boat plumb and true to form, so that too much attention cannot be given the matter of shoring and bracing.

Ribbands are long strips of wood, preferably yellow pine, which are bent over the moulds and fastened to them to give a continuous form for

fitting the frames. It is impossible to give exact information regarding the dimensions and spacing of ribbands as this depends on the size of the boat, size of frames, method of framing, and the distance apart of the moulds. For a small boat with rather light frames and a mould spacing of not more than three feet, they may be from 1¼″ × 1½″ to 1½″ × 2″ and spaced 8″ to 10″. A forty-foot cruiser with a mould spacing of four feet should have them 1½″ × 2″ to 2″ × 2½″ spaced 10″ to 12″. These sizes are for amidships and the ends are tapered to suit the curve.

The larger the ribbands and the closer they are spaced, the more certain you are of keeping the form fair, but very heavy ribbands are both hard to bend and hold, and there is risk of forcing the moulds out of place. Taking this into consideration ribbands should be put on in pairs, one each side, in order to equalize the strain on the moulds. It is desirable to have them in one piece, but if your material is not long enough, splice them as shown on Plate 3 so that the splice will come near amidships where there is little curve. They are fastened in the stem and stern rabbets and to the moulds with one screw in each bearing.

When running a ribband fasten it amidships first, then bend it around and put in the fastenings, working from amidships toward the ends. Put

on the top one first, letting it follow parallel to the sheer line and two or three inches above it, then fill the space between this and the keel, spacing them a little closer in the bilge than for the flatter bottom and top sides. Although only temporary, the ribbands should run fair, following as nearly as possible the run of the planking, in fact it is a very good plan to lay out the plank roughly before putting the ribbands on. Very often the ribbands between the stem and the first mould will not bend so that a fair section is obtained, and it pays to make an extra mould, or fit a frame at once, to hold them in line. To help this operation some builders secure the ribbands in the stem rabbet with cleats instead of screws which allows some end movement.

If the lines were properly faired and the subsequent work carefully done the ribbands will all run in nice true curves; however, if this is not the case the moulds may be trimmed a little, or shims placed under the ribbands to bring all fair. If much of this correcting has to be done the athwartship fairness must be checked by bending a batten on the inside where it should touch all the ribbands and show a true curve. When all the ribbands are in place and there is no question about the fairness of the form we are ready to fit the

frames or "frame out" as boat builders term it. These ribbands remain in place as long as possible and are removed one by one to make way for the planking.

CHAPTER VII

FRAMING

THERE are two kinds of frames in general use for small boats, i.e., frames sawed from natural growth crooks or knees, and frames steam bent from straight grained lumber. Those sawed from crooks are seldom used except in combination with steam bent ones or for special construction. Steam bent frames are made in two ways, i.e., bent over a form and fitted in the boat cold, or bent directly into place while hot. The latter method is by far the simpler and may be employed for frames up to about one inch square but above this size they are rather stubborn to bend and apt to break. Even if a larger frame can be handled there is a continual tendency to straighten out which does the boat no good.

The best material is straight grained white oak, preferably cut from the butt of the tree, and not too dry. If possible, bend the frame so that the plank fastenings will cut across the annual rings and not between them, as the wood bends better this way and there is much less tendency to split

when the planking nails are driven. See Fig. 10.

In order to bend the frames they must be made pliable by steaming and a steam box will be needed long enough to take the full length. As the forward end of the garboard strake and perhaps some of the other planks will also need to be steamed,

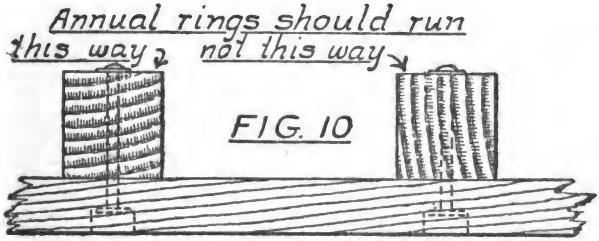


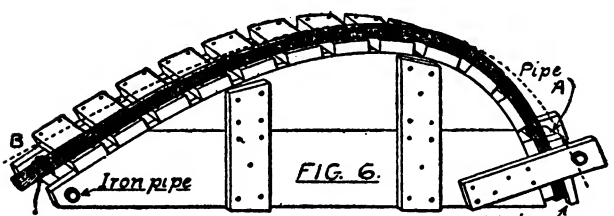
FIG. 10

the box should be made large enough in section to take them. It must be strongly built and made as steam tight as possible, by laying candle wick in all the joints as the box is put together or caulking after it is completed. A sliding door that can be quickly set tight with a wedge should be arranged at one end.

Steam can be generated in an old boiler or pot of some kind, even a large tea kettle will answer, rigged up so a fire can be built under it. A discarded expansion tank from a hot water heating system or an old cylindrical gasoline tank mounted on a brick fireplace makes an ideal outfit, but I leave it to the amateur to rig up something

from such material as can be obtained. It should be arranged convenient to the boat and be capable of maintaining steam for the full steaming time required. The steam may be led to the box through any kind of pipe and should enter it at the bottom near the end opposite the door.

Fitting Frames Cold. For bending frames outside the boat, make a form as shown in Fig. 6.



FORM FOR BENDING FRAMES.

To get the shape of this, bend a heavy wire of soft material inside the ribbands from keel to deck, about amidships, and then make the form with considerably more curve, but of the same character. The dotted lines show how a frame will open out when released so that the form must be made to allow for this. Even after the frame is taken off the form, it should have a little more crook than the finished frame, so that it can be fitted by straightening where necessary. It is a very easy matter to take some of the bend out but impos-

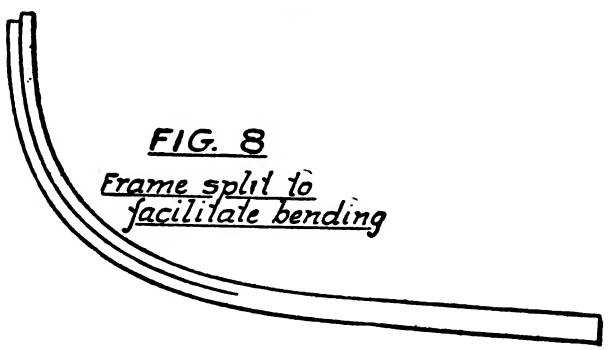
sible to put more in after the frame is cold and set.

Select straight grained material, rip it up in strips about a foot longer than the finished frame and plane all sides. Steam them until pliable which will take a half hour or more, depending on the size, then taking them from the box one at a time, slip one end quickly under pipe A on the form, pull the other over and down and tie it to pipe B with a heavy cord. This operation should be accomplished without loss of time, but the actual bending must be done with a deliberate, steady pull so that the fibers of the wood have time to adjust themselves to the new shape.

By varying the amount of frame pushed under A and the distance bent over, various shapes may be obtained on the same form which will answer for all the frames amidships and for some distance forward. For the after body pad out the form by nailing extra pieces across it to make the curve sharper and for the fore body alter it to make the curve flatter. It requires judgment and practice to bend frames well so the amateur had better experiment with a few before risking any number.

Large frames have a tendency to splinter on the outside where the wood is stretched, which may be stopped to a great extent by placing a strip of strap iron, about the same width as the frame,

on the outside. This strap to be effective must bear tightly on the frame and to accomplish this the professional's outfit has a forging riveted to one end which hooks over the upper end of the frame. The other end is slipped under pipe A, with the frame, and wedged fast. When only one

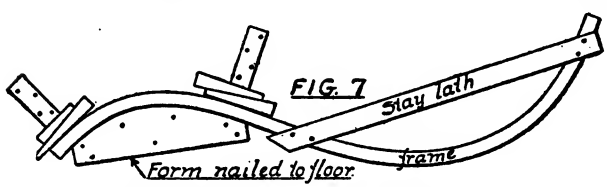


boat is to be built an ordinary iron clamp may be substituted for the hook.

Leave the frames on the form over night, or longer, and when taken off fasten a stay lath on them or wedge them somewhere to hold the bend until ready to fit them in the boat. Sometimes when a frame is too large for a quick bend it is ripped part way as shown in Fig. 8 which makes bending easier. For frames having a reverse curve bend the main part first, let it dry and nail a stay lath on it to hold the shape, then steam

and bend the other end. Only the part to be bent should go in the steam box the second time and rags will need to be packed around the frame to hold the steam. The second bend is best made around a form nailed to the floor or bench. See Fig. 7.

Before starting to fit frames it pays to mark their position on the inside of all the ribbands and keel, which may be done with a thin batten, taking



BENDING REVERSE CURVE IN FRAME.

care that they go square across the boat. An exception to this is in the case of very full bowed boats or full canoe sterns when a few frames at the ends are canted, that is fitted more nearly square to the planking, which reduces the bevel. Begin fitting the frames amidships. Place a suitable one in the boat against the ribbands and shift it up and down until it fits best, then if necessary open it out, a little at a time, so that it lays against all the ribbands in a fair curve.

A convenient device for straightening frames consists of two blocks securely nailed to a post

or rigid bench as shown in Fig. 9. The frame is placed over one and under the other and straightened by pulling on the free end. Cut the foot to

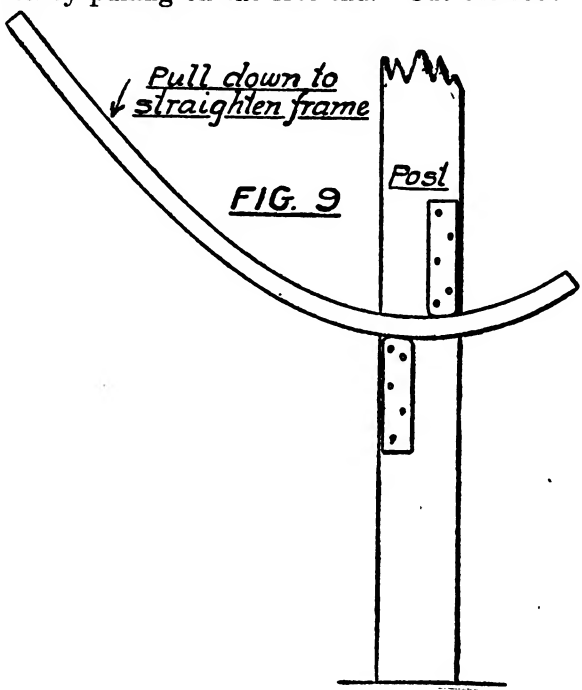


FIG. 9

fit the keel and if everything is all right make a duplicate from it for the other side. Hold the frames in place with temporary wire nails toed through the corner of the ribband into the frame and nail the foot permanently to the keel.

If a frame has too little crook it will probably answer for some place farther forward or if too much, some place farther aft, but in every case they must lie naturally in place, as any attempt to force them will make trouble later and result in a poor job. Forward and aft they will need to be beveled to suit the curve of planking. The amount necessary can be judged by the eye, or measured, and the bevel made with a drawing knife or plane. In spite of all care it may be that when the framing is done the frames do not present a perfectly fair surface for the planking to land on, and if this is so, the full ones may be trimmed off some and shims (thin strips of wood) placed on any that are slack. The latter method should be employed only to avoid too much cutting.

Fitting Frames Hot. The work of fitting frames hot varies slightly with different types. Take first a boat set up with moulds and ribbands. The frames are prepared and steamed the same as for bending over a form and the ribbands marked on the inside. If the frames are fairly light take them one at a time from the steam box, cut the foot quickly to fit the keel and nail it, then bend it in place, twisting in the required bevel as you go. Do not simply push it in place, but put your foot, knee, or hand on the inside and pull the head of the frame inboard, making the bend more than

required; then let it go outboard against the ribbands and note the result, repeating the operation until it fits perfectly.

By working in this manner from the keel up, a frame can be made to touch all of the ribbands and the tendency to straighten out is reduced. Secure it to the top ribband with a clamp and if it does not touch all of the ribbands a few taps downward on the head with a hammer will help. Be sure it is in its proper position fore and aft and fasten it with slim wire nails driven through the frame into the ribbands or through the corners of the ribbands into the frame. This work is best performed by two men, one inside the boat doing the major part and the other outside tending the steam box and assisting where possible. Frames that extend from side to side in one length are handled in the same way except that two should do the bending, one each side, otherwise the frame will become cold and stiff before both sides can be bent.

Often frames which can be readily bent in this way are too large to bevel by twisting also the cutting of the foot takes too long so that the job is best done in two shifts. First bend them in place with more curve than required and let them cool, then fit and bevel them the same as frames bent over a form. The extra bend is made by

tacking strips of wood on the inside of the ribbands, above and below the bilge, increasing the thickness of these strips from the bilge to the deck and from the bilge to the keel. A few trials will give the amount necessary.

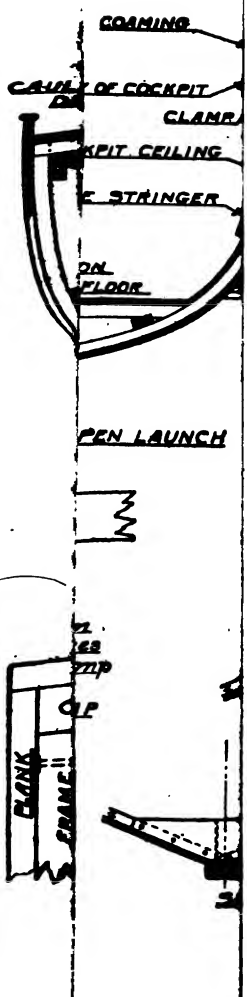
Put in all the frames not interfered with by the moulds and fasten cross spalls, from side to side, to hold the boat in shape. These should be spaced about the same as the moulds and may be nailed to the frame heads or the top ribband. Also brace the frame to the overhead beam or floor as the case may be. Transfer the sheer heights from the moulds to the nearest frames. The moulds may now be taken out and the remaining frames, if any, fitted or the moulds can remain in place until the floors are fitted and fastened which is the safer way when the frames are light.

When the planking is to have battens on the inside of the seams, these battens must be flush with the outside of the frame so that the plank is supported between them. To obtain this condition the moulding of the frame may be increased an amount equal to the thickness of the batten, or a strip of wood the width of frame and thickness of batten steamed and bent with the frame. This strip or liner is usually of light wood to save weight. See Fig 2, Plate 8. As each plank is

fitted, short sections the width of the batten are cut out of the liner, and the pieces between battens are secured to the frames with a couple of small wire nails.

Take next a lapstrake boat that is already planked, the frames to run from gunwale to gunwale in one length. Mark lightly, on the upper edge of each strake, the position of the frames, then in the center of each plank lap and half the width of frame from these marks bore a hole for the frame fastening. Take a frame from the steam box and grasping it in both hands, bend it and push it down to the keel, securing it there with a nail, then with the hands bend and twist it so that it lies snug against the planking and secure it to the top edge of the sheer strake with a clamp. If it does not bear against all the laps, tap the end with a hammer.

See that the frame is exactly to the marks and put in the fastenings at the laps, starting at the bottom and working up. These fastenings are copper nails riveted, but the riveting is left until all the frames are in. A hot steamed frame is not nearly so liable to split from driving a nail into it as a cold one, nevertheless for good work, holes should be bored and the nails driven so that the chisel points cut across the grain of the frame. Boats of this kind are usually without ceiling or


COAMING
OF COCKPIT
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other finish on the inside so that the frames should be neatly finished and the inside corners rounded.

In the V bottomed type of boat the frames are straight or nearly so which makes the work comparatively easy for the amateur. Where the side and bottom frames meet at the chine, they must be connected in some way. Fig. 4, Plate 7, shows three methods. Whatever the arrangement, the part connecting the frames must be well fastened to the chine. This chine is simply a corner piece of oak, rabbeted for the plank, but is rather difficult to make. The shape (cross section) may be laid out at each section on the body plan and the chine made accordingly, or the piece may be roughly shaped, bent around the moulds and the proper form obtained direct from the boat. Sometimes the rabbet is omitted and the bottom and side planking simply nailed to the chine, the same as a flat bottomed row boat, but such construction is not first class.

There is another type of framing which has come into vogue during recent years for hydroplanes, V bottomed boats, and sometimes round bottomed boats. So far as I know it has no particular name, but it corresponds to the Isherwood system used for steel ships. The frames are larger than usual, especially the moulding, and spaced much farther apart (two to three feet).

For a V bottom the frames are best made from hackmatack knees, but may be made of straight material, connected with knees at the chine or lapped. For round bilge boats they must be of knees or are worthless. The planking is of normal thickness but in lieu of other frames is stiffened with fairly heavy seam battens which are let into the frames. Sometimes light frames are fitted between the heavy ones when the seam battens may be lighter. This construction is shown Fig. 3, Plate 7.

Floors. When the frames are all in place we are ready to fit the floors, which are pieces of wood connecting the pairs of frames across the keel. They are preferably made from natural oak crooks and for extra light construction of hackmatack knees, but as oak crooks are difficult to procure it is common practice to make them of oak plank. Plates 4, 5, and 6 show the types in general use. The "siding" (thickness fore and aft) should be about twenty-five per cent. more than the frames and the "moulding" (depth) at the "throat" (keel), when made from crooks, fifty per cent. to one hundred per cent. more than the frames. They should taper from the center so that the ends are about the same size as the frames. Under the engine in a power boat or in the way of the lead keel of a sail boat it is advis-

able to make the floors extra heavy; at least twice the siding of frames.

When made of straight grained material floors need to be extra deep in order to avoid cross grain, so if a center keelson is called for, one is practically forced to use crooks otherwise the keelson would be too high. All things considered the best arrangement for small and medium sized boats is to omit a center keelson and make the floors of plank, fixing the height, if not too great, to take the cockpit or cabin floor as shown in Fig. 2, Plate 4. They may be fitted either on the top or on the side of frames, the latter way being better for numerous reasons.

As a rule floors are located on the forward side of frames in the fore body and the after side in the after body, which arrangement simplifies fitting; however, there may be other considerations, light frames, for instance, making a departure from this practice advisable and the plans should be followed. In way of the shaft log, where the regular floors are cut, special construction must be made to tie the sides together. This may be accomplished with metal straps and brackets in combination with the wood floors. In the same way floors at the side of a center board trunk should be made deep and fastened to the trunk logs with metal brackets or angles. Plate 6 shows three

types of floors suitable for a centerboard boat.

The simplest way to get out the floors is to make a template for each one from any thin wood, and if each side is made separately, lapped at the keel, and fastened together with tacks, this work is quickly done. It is only necessary to obtain the shape of the lower edge, the top of floor being lined out and cut to suit the conditions. After the floor is cut out fit it in place and cut the necessary bevel so that the planking will bear on it the full width. The advantage of having the floors on that side of the frame nearest the ends of boat is now evident, because the template is made to the edge of frame, the floor made like it, and the bevel cut from this edge; whereas if the floor was on the other side of the frame, an allowance of extra material for the bevel would need to be made. Notwithstanding this advantage, if the frames are light and strength a prime consideration, it may be better to reverse the arrangement, which gives more bearing surface between frame and floor and better fastening.

Secure floors to frames with at least three fastenings each side and to the keel with one good fastening if it is narrow and two if it is of the wide plank type. If the keel is heavy and deep, drift fastenings will do, but a through riveted bolt is better; or some combination of the two

may be used, such as every second or third one a riveted bolt and the others drift bolts. When there is a center keelson these fastenings should go through it, thus tying the whole structure together.

At this time attention should be given the limbers which are passages for the bilge water to flow to the pump well. Plates 4 and 5 show various kinds. When weight is no objection it is a good plan to fill the bottom with cement or asphalt to the top of the frames and bore a hole through the floor at this height, if it is of the deep plank type. This arrangement insures a clean sweet bilge. If for any reason cement is not desirable the limber hole must be cut from both frame and floor at the lowest point, either over the keel or garboard strake. If the latter it must be kept a little distance out so that the lower edge of garboard strake will have a bearing. It is always well to keep the holes in line and rig a chain through them, from end to end of the boat, so that they may be kept clear of dirt by pulling the chain back and forth.

Keelsons, Clamps, etc. The next job for ordinary boats is fitting and fastening the keelsons, stringers, clamps, and shelves. These are longitudinal stiffeners fastened on the inside of frames, and the sizes and positions should be shown on the

plans or specified. Yellow pine is used almost exclusively except in very light construction when Oregon pine or spruce may be substituted. When possible they should be in one length, but may be scarphed if necessary, or lapped and edge fastened in the case of a small bilge keelson or stringer which will be out of sight in the finished boat. It is common practice to taper these members at the ends which makes bending easier and gives a more scientific distribution of material, although the labor of preparing them is greater.

The clamp, shelf, and side stringers usually extend the full length of boat; bilge keelsons stop a little short of bow and stern, and engine or side keelsons are of various lengths depending on conditions. It is usually necessary to steam the forward ends, especially the clamps for full bowed boats, and this may be done by putting them as far as possible in the steam box and packing rags in the opening to hold the steam.

Regarding the position and run of keelsons and stringers, the plans should be gone over carefully to be sure that they will not conflict with any other parts of the construction or joiner work. Run a batten on the inside of frames and mark some of them as a guide for quickly getting them in place. The position of the clamp, and shelf

if there is one, demand more careful attention as the deck beams land on them and all unnecessary cutting of either clamp or beams must be avoided. The safest way is to run a batten on each side, on the outside of frames, at the sheer line. These battens should be the same thickness as the planking and the outside upper corner should be the thickness of deck below the sheer heights marked on the frames. Fair the battens carefully and test with a straight edge and level to insure both sides being alike.

Next make a beam mould of material about ⅞" thick as shown in Fig. 2, Plate 9, and described in the chapter on decks. By placing this mould across the boat as shown in Fig. 1, Plate 7, the frames may be marked on their sides for the top of deck beam; then the depth of beam set down and the bottom marked, which is also the top of clamp. Sometimes the top of clamp is beveled the whole length to suit the under sides of beams; in other cases a notch the width of each beam only is beveled, or the beam may be notched over the clamp. If there is a shelf it is good construction to keep it or the clamp slightly above the bottom of beams and notch the beams over it. See Plate 7. Whatever the arrangement, mark every third or fourth frame so that the clamp may be bent in

at the proper height. Before taking the battens off mark the top of sheerstrake on all the frames which is of course the top of the batten.

Before steaming these members you should plan how they are to be gotten in place as braces and cross spalls will undoubtedly necessitate a somewhat roundabout way, also have a number of screw clamps ready so that the work may be quickly done before the stick cools and becomes stiff. They are riveted or bolted to every frame, driving the fastenings from the outside. Where the size is not too great large nails riveted over burrs answer very nicely. Keelsons and stringers, unless very wide, have one fastening at each frame, but the clamp often has two; one through the frame and one through both plank and frame. When there is a shelf the fastenings are variously arranged depending on the construction. Plate 7 shows several combinations. The clamps are tied together at the bow with a breast hook and kneed to the stern if it is of the transom type. Side stringers are often fastened in the same way.

When the frames are very light it is often better to start planking from the keel and fasten the keelsons, etc., as the planking reaches them. By working in this way the planks tend to regulate the frames as you go, while if the fore and aft

members were fastened this fairing would be impossible.

The gunwale in a boat with no deck corresponds to the clamp in decked boats. In the ordinary small row boat it is simply bent inside the frames, leaving an open space between it and the sheerstrake. Larger boats of this type have a heavier gunwale which is fitted down over the frame heads and the sheerstrake is fastened to it. In either case a half round moulding or wearing strip is fastened at the top of the sheerstrake outside. See Fig. 2, Plate 7.

Engine Foundation. To build a foundation of sufficient strength to carry the engine and take the propeller thrust is a simple matter, but the principal object is to arrange the construction so that the engine vibrations are carried to many members of the hull proper, which tends to destroy them and prevent any local panting, or vibration, of the hull.

First the floors in the neighborhood of the engine must be extra heavy and as deep over the keel as the design of the engine permits. On top of these and notched over them a little are the engine beds proper, set perfectly straight fore and aft and with the proper rake on top for the engine. The depth of these cannot be definitely stated as

it will depend on the general construction and depth of floors.

Sufficient wood must be provided to take the holding down bolts for the engine which in most cases are either lag screws or hanger bolts. Now the simplest arrangement would be to have these pieces extend well forward and aft of the engine, but unfortunately engine manufacturers make the bed plates so narrow that the fly wheel interferes. The best way then is to make the engine beds proper from a point immediately abaft the fly wheel to a point several frames abaft the engine, and bolt them to the inside of two keelsons which extend some distance fore and aft.

Where possible chocks should be fitted between the engine beds, and outside of them, to prevent any side swaying. The whole structure must be thoroughly bolted together, screw bolts preferred as it is then possible to take up any looseness that may develop. Bolts securing the bed logs to the floors in way of the engine must be well countersunk on top and when putting them in, the holding down bolts must be considered so there will be no interference.

Use oak for the logs, floors, and chocks, and yellow pine or oak for the keelsons and see that it is sound and fairly dry. Stretch a string tightly to represent the center of shaft and work

from it. It is safer to get out the logs a little higher than required and trim them off after everything is bolted fast or make them about ¼″ too low and fit shims of hard wood to line up the engine. Particular care must be taken that the logs have the proper rake and are "out of wind," in other words present a perfect plane for the engine to rest on, otherwise the shaft cannot be lined and the engine will be subjected to a strain when the holding down bolts are set up.

CHAPTER VIII

PLANKING

PERHAPS planking presents more difficulties to the amateur than any other part of the construction, but there is no mystery about it and once the principle is grasped it should be a comparatively easy matter to cover a frame so that it is both strong and watertight. The principal difficulty for the inexperienced is to proportion and run the "strakes," as the planks are called, so that the material is used to good advantage and the seams show fair and "sweet" from all points of view. A planking job may look well when viewed from the side, but an end view, which foreshortens the planks, may show unfair curves, reverse curves, and other defects. I strongly advise the amateur to examine critically the work of professionals when much information will be gained.

There are many different methods of planking, but only four will be considered as they no doubt fully cover all amateur requirements. These are

carvel, ribband carvel, clinker, and double planking. See Plate 8.

Carvel or smooth planking is the most common form and may be used for all types of boats, providing the planking is not too thin to hold the caulking ($\frac{3}{8}''$ is about the minimum). The planks are fitted edge to edge and the seams caulked with cotton or oakum to make them watertight.

Ribband Carvel, also called batten seam, is just like carvel planking with the addition of a ribband or batten fitted over the seams on the inside to which the planks are riveted. Thin planking may be used and a strong job obtained the same as with clinker planking but it has the advantage of being smooth on the outside and if well done requires no caulking.

Clinker or lap strake, which is principally used for small boats, has the edges of the planks lapped, like the clapboards of a house, and riveted together. For small boats that are kept out of the water for a large part of the time, this construction is particularly suited as the seams are not so likely to open and leak due to shrinkage. Lap strake also permits the use of thinner material than is possible where caulking is necessary, at the same time it makes a strong boat due to the skin being practically one piece.

Double Planking consists of two thicknesses all over, with the seams of the outside skin in the center of the inside planks. Thick paint or varnish is smeared between them and the two skins closely fastened together between the frames, in addition to the regular fastenings in the frames. Sometimes the inner skin is covered with muslin or other fabric, laid in paint, varnish, or crude turpentine.

Whatever the kind the same methods are employed to get out the planks to shape, but fitting and fastening varies somewhat. To save labor, boards for planking should be obtained from the mill, planed to a thickness somewhat greater than the finished planking to allow for planing and finishing. For the topsides and bottom very little extra thickness will be required, but in the bilge, where the turn of frame is rather quick, an allowance must be made so that the planks may be hollowed on the inside to fit the frames and rounded on the outside; an eighth to three-sixteenths is usually sufficient.

Planks should be put on in long lengths and the material ordered should be in such lengths as will make the best shift of "butts" (joints in the planks). No butts should be in the same frame space with less than three strakes of planks between, and no butt in adjacent strakes should be nearer than three or four feet. The ideal

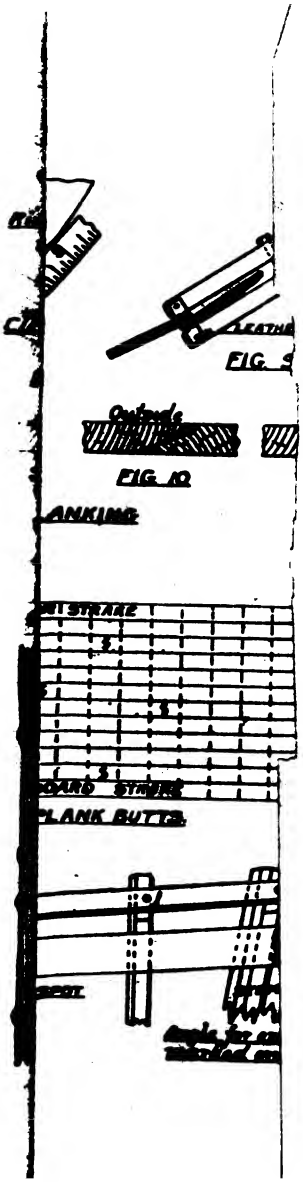
planking job is without any butts at all, but this is possible only in small boats. When fixing the position of butts, it is a good plan to draw a number of parallel lines representing the number of strakes to be put on, and across these draw dotted lines to represent the frames; then lay out the butts to good advantage and order the material accordingly. See Plate 8. Butts are always made between frames and the plank ends connected with an oak butt block on the inside, to which both are securely fastened.

Lumber is usually manufactured in lengths of an even number of feet, such as 14, 16, 18, etc., and is generally checked at the ends, making the available length six inches to a foot less, all of which must be considered when laying out the strakes. More boards than actually needed should be ordered as some are likely to be defective and no doubt a few will be spoiled. If the planking is cedar or other soft wood, the top strake, called "sheerstrake," is best made of oak or yellow pine as it holds the deck and other fastenings better and also gives additional strength at this important place.

Carvel Planking. Let us first consider the planking of a small launch by the carvel method. The usual procedure is to put on the sheer and one or two adjoining strakes first; next the "gar-

board" (plank next to the keel) and two or three adjoining strakes (broads); then alternate top and bottom so that the last plank (shutter) is in the bilge about midway between deck and keel. The first job is to decide on the number of strakes required and determine their widths amidships. Bend a thin flat batten inside the ribbands, near amidships, and obtain the girth or distance from keel to deck; then lay out the strakes on it. The garboard should be the widest. From the garboard to where the bilge begins to turn, the strakes gradually diminish in width, so that in the bilge and topsides they are the narrowest and nearly uniform in width. As a rule the sheerstrake is a little wider than the others in the topsides.

One would naturally suppose that the width of planking would be somewhat proportional to the thickness, but this is not so, in fact thin planking is often wider than thick. In the majority of cases the widths of planking amidships will run about as follows; garboard and broads 6″ to 8″, sheer 4″ to 6″, and the remainder 3½″ to 5″. As the girth amidships is greater than at the bow or stern it follows that the planks must grow narrower as they approach the ends, similar to the staves of a barrel, and this taper should be uniform, preserving as far as possible the same relative widths. The garboard in many boats is an


LEATHE
FIG. 9
Outside
FIG. 10
ANKING
STRAKE
PLANK BUTTS
SPOT

exception, for it will be found that in order to have a good line on the upper edge the plank will be as wide, if not wider, at the forward end as at amidships, and although the keel may be straight, the plank when lying flat will have a very peculiar hollow curve to the lower edge, owing to the twist in it.

Mark on the frame from which the girth was taken the width determined for the sheerstrake and run a batten on the frames for the lower edge, tapering it a little fore and aft. See that this is fair and mark the frames, stem and stern. We now have the top and bottom edges of this strake fixed, and the problem is to cut a plank so that when bent around the frames it will fit without bending it edgewise. To do this you will need what is called a "spiling batten." This should be of soft wood from $\frac{1}{8}''$ to $\frac{3}{16}''$ thick, 3″ to 5″ wide, and a little longer than the longest plank to be used. It need not be straight, in fact a curve edgewise will often be an advantage and sometimes a necessity, but it should be planed.

Fasten this lightly on the outside of the frames with its upper edge a little below the marks representing the top of sheerstrake. Fig. 12, Plate 8. It is important that the batten follow the twist of the frames and lie flat against them, otherwise allow it to take what shape it will; in other

words, do *not* try to make it bend edgewise. The object is to have it occupy approximately the same position as the sheerstrake so that the difference in shape between this batten and a plank that will fit may be ascertained.

If the sheer is excessive or the form of boat causes the batten to come more than say 2″ from the sheer marks at any place, another should be used that is more curved and follows the sheer better. Now take a pair of carpenter's compasses and set the legs to an opening a little greater than the widest gap between the sheer marks and the spiling batten. Place one leg of the compasses to a sheer mark and with the other prick a hole in the batten square down from the sheer line. Put a chalk mark around it for identification. Do not use a pencil as the batten will be used repeatedly and there would soon be confusion, but chalk is easily rubbed out with the fingers or a rag.

Repeat this operation, with the same opening of compasses, at intervals of 1½′ to 2′, depending on the frame spacing, also at the stem, stern, or butt as the case may be. Number these spots with the frame numbers, also mark the numbers on the top ribband and the keel for ready reference. Assuming this strake will be in two pieces and this is the forward one, draw a line across the batten

where the stem rabbet crosses it, also mark where the butt will be.

Next tack the spiling batten on a suitable board and using the compasses with the same opening as before, reverse the operation, by setting off from the holes in the batten; pricking similar ones in the board. See Fig. 13, Plate 8. In order not to waste material the batten should be arranged so that this row of marks is near the edge of the board or the edge of the sap wood. Mark the ends, take up the spiling batten, and run a fair line through the prick marks, using a suitable batten and pencil. It is obvious that this line will represent the proper shape for the top of sheerstrake regardless of its appearance while lying flat. Now at each frame from which a spiling was taken, obtain the width of plank; set off these widths on the board and draw a line through them for the lower edge.

The plank is now ready to saw out, but before doing so it is well to study just what the conditions are regarding the upper edge. It will be remembered that the marks on the frames represent the outside upper corner of the sheerstrake so that a little extra width must be allowed for the crown of deck. Saw out the plank accordingly, bevel the top edge for the crown, and plane the

lower edge square. Now fit it carefully in the rabbet, clamp it in position, and if everything is right put in the fastenings.

After each plank is fitted a mate for it should be lined out for the other side of the boat. The after part is gotten out in the same way except that the butt must not be cut until the plank is fitted at the after end and clamped in place, then cut the butt so that the joint will be tight on the inside and very slightly open on the outside. To secure the butt make an oak block to fit neatly between the frames, a little wider than the plank and the same thickness. Each plank end is fastened to it with three or five fastenings, depending on the width. Fig. 14, Plate 8.

A professional would probably put two or three more planks on the topsides now, but it will be safer for the amateur to tackle the garboard next as widths for the remaining strakes can be better determined. First take a spiling for the lower edge in the manner described, except that the spiling batten must be somewhere near a fit, especially where the rabbet rounds up into the stem and the spilings at this point should be close together and square out from the rabbet. When spotting these on the board draw a small arc of a circle instead of pricking a hole and bend the batten, when lining out, so that it just touches them.

While the spiling batten is in place on the frames test the rabbet, especially around the forefoot, and trim out if necessary so that the plank will fit properly. Now set off amidships the width decided on for the garboard and run a batten on the frames for the top edge. The width, forward and aft, of this and the next strake or two should be such that any excessive curve is worked out, so that the following strakes may be fairly straight when lying flat. However, do not go to extremes for if these seams curl up too much at the stem they look bad and the remaining strakes are too narrow.

The spiling just taken shows the shape of the lower edge of the garboard from which we get some idea how wide to make it at the forward end. For the type of boat under consideration, this width will probably be about the same as amidships, perhaps a little wider, but see that the batten for the upper edge runs fair and looks well from all directions. If the boat has a transom the width there should be a little less than amidships. Set off the widths thus obtained and draw the line with a batten, then saw out and plane the edges. The upper edge is planed square, but the lower edge should be beveled slightly so that when the plank is forced tight in the rabbet and against the keel it is a little open on the outside.

No doubt the forward end of this plank will need steaming and require two men at least to get it on, so have the work all planned and plenty of blocks, clamps, and wedges handy. The best way is to fit the end in the stem rabbet first and clamp the top edge to the stem, then bend the plank quickly in place, forcing the bottom edge up against the frames with shores to the floor, driving wedges between them and the plank. To set the plank edgewise so that it fits tight against the keel some devices must be attached to the frames and wedges driven between them and the plank edge, or regular chain planking clamps used. Dealers in marine hardware handle such things, but lacking them, the amateur can get along with oak blocks clamped to the frames, and if two or three screws are put through them with their points projecting slightly, they will hold much better. Always put a piece of wood between the plank and a wedge so that the wood is not bruised.

If the plank fits properly it should be fastened, otherwise let it cool. It may then be taken off, trimmed to fit, and possibly put back without steaming again. This is the hardest plank to fit and fasten and if well done, even at the expense of a board or two spoiled, you should be well pleased for the remaining ones will be comparatively easy.

The first broad is next put on, taking spilings and running a batten for the top edge, the same as described. The width amidships has been determined and we know that the plank will taper some at the ends, but the amount of this taper is governed by two considerations. First we want the seams to show good and fair lines and second, the planks should be as straight as possible in order to cut the material to advantage. A professional goes about it in an offhand manner, with apparently no thought, but he is governed by long practice. The amateur cannot hope to do this and must feel his way, which of course makes more work.

First run a batten for the top edge, making the taper proportional to the frame girth at every point. To do this, find how many strakes, of this width, would be required to fill the space between garboard and sheer amidships and divide the other spiling frames into the same number of spaces. Of course only the lower strake need be actually marked. Run a batten to these marks and see that it is fair.

Next take a spiling and line out the lower edge on a board. If this does not show an excessive curve and the batten gives a good looking line from all points, the widths shown by the batten may be used. If it seems desirable to make the plank

wider at the forward end in order to straighten it, or perhaps show a better line when looking end on, do it, but in moderation. The next few planks are treated in the same manner, which brings you to the turn in the bilge from which point all planks may be of the same width and taper.

The widths for the remaining planks may be spaced off on the spiling frames, but a simpler way is to use a "planking scale" or "diminish batten," which is a simple thing and made in this way. Take a thin batten ¾" or 1" wide and mark on it the greatest girth or space between the planks, which will be found near amidships; also mark on it the least girth wherever it may be found. Suppose it is decided to put on eight strakes and eight divided into the greatest girth gives 5" for the width of each strake at this point. Call the mark on the scale that corresponds to this girth 5". Now divide the smallest girth by the same number of strakes which gives, we will say, 3½". Call the mark corresponding to this girth 3½". Then divide the distance on the scale between 3½" and 5" into a scale of eighths, which in this case will be twelve spaces, and mark them 3⅝, 3¾, 3⅞, etc. See Fig. 15, Plate 8.

A little thought will show that wherever this scale is applied the correct width of plank is at once seen for that place. The width at each spil-

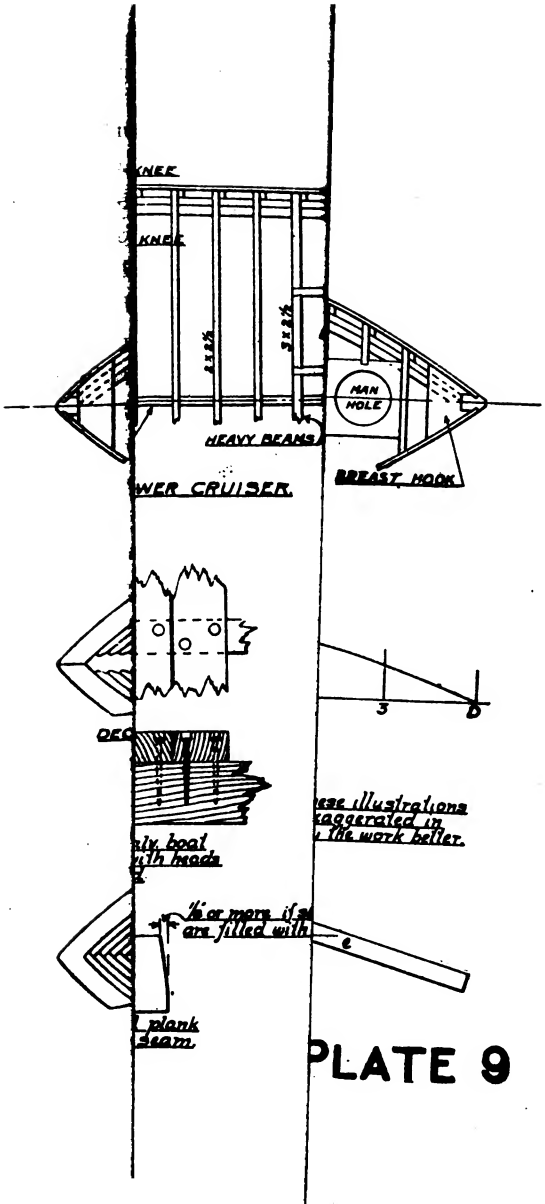

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PLATE 9

ing station should be so scaled and marked on the sheerstrake for easy reference. With the widths thus determined it is of course unnecessary to run any battens on the frames unless it appears that the strakes are not running fair, but a spiling must be taken for each plank.

Where the frames are curved the planks must be hollowed on the inside to fit. The amount necessary may be judged by holding a rule against the frame and a board sufficiently thick used. A wooden smoothing plane, rounded on the bottom with the iron ground to suit, makes a good tool for this work. After the plank is hollowed run a scratch gauge, set to the plank thickness, on both edges and roughly round the outside. All seams must be tight inside and slightly open outside so that the caulking may be entered, the planks must therefore be beveled more or less which bevels are taken from the boat at the same places the spilings are made. The best way is to take all the bevels for a plank at one time and mark them on a suitable piece of wood.

For the wide planks on the bottom it is usual to use three fastenings at each frame, two of which go in the frame and one in the floor, reversing the arrangement in the adjoining strake so that the fastenings are staggered. Narrow planks in the bilge and topsides have two fastenings in each

frame and they should be staggered as much as the width of frame allows. If copper is used, brass screws must be substituted in the stem and stern rabbets, in deep floors or any other place where the fastenings cannot be riveted. Where the garboard twists up to the stem the fastenings must be quite close together.

After the planks are all fastened go over the whole boat carefully and ream out any loose or rotten knots with a taper bit and plug them with soft wood, dipped in thick paint or waterproof glue. Also plug the countersunk nail holes, setting the plugs in white lead, if the boat is to be painted, or in varnish if to be finished bright. See that the grain in the plugs runs generally the same as the plank and do not hit them harder than necessary or they will swell out later and make an unsightly boat. These plugs in any size or wood may be bought readymade. Trim off the plugs with a sharp chisel and go over the planking with a jack plane and plane it fair. Use long strokes and be very careful to take off the high spots only. By passing the hand quickly up and down the humps will be felt or can be seen by bending a thin batten around. The seams form sight edges which will show any fore and aft unfairness.

The boat is now ready to caulk and as this is a very important part of the work and requires

skill to do it properly, I strongly advise getting a professional for the job. If you wish to do it yourself, obtain cotton prepared for the purpose which is in strands easily split to suit the size of seam. Start at one end of the boat and tuck an end of the cotton strand in the seam, then with the caulking iron gather the cotton up into a small loop and drive it in, then another loop and so on along the seam, varying the size of the loops to make just the right body of cotton to properly fill the seam. Now go over it again and drive the cotton home so that room is left for putty. If a seam is too tight open it with a dumb iron.

When the planking is thin, $\frac{5}{8}''$ or less, caulking wick may be substituted for the cotton and either driven with a thin iron or rolled in with a caulking wheel. Sometimes for small boats, when a particularly nice job is desired, the planks are tightly fitted without any bevel for a caulking seam. The seams are forced open with a wheel or dumb iron, the wick rolled in, and the wood sponged with water, which brings the seams back to their original condition.

When the caulking is finished, paint the seams thoroughly with a moderately thick paint, working it in well so that it covers the cotton, and wipe off any surplus. A special narrow brush, called a seam brush, is made for the purpose. After the

paint is dry the planking should be planed again, using a plane with the iron set fine, then scraped diagonally with a sharp cabinet scraper and well sand-papered. This work must receive particular care as any unfair places will show very plainly after painting. When the smoothing is done give the hull inside and outside a coat of lead and oil paint.

While the same methods apply to all carvel planking jobs, regardless of form, boats other than the type considered require different treatment as regards the arrangement and widths of planks. For instance, the garboard of a sail boat with spoon bow and deep keel would be very short, perhaps only one-third the length of the boat, and rapidly diminish from a width of six or eight inches amidships to nothing at the ends. Each strake above this would be longer until the deck is reached. It is beyond the scope of this book to consider all types and conditions, but no doubt the amateur can inspect a boat similar to the one he is building and obtain more information in a few minutes than could ever be acquired from description.

Clinker Planking. Clinker or lapstrake planking differs from carvel planking in many respects. In the first place, the planking is done directly on the moulds and the frames fitted afterwards,

which demands that the planks be very accurately lined out as any forcing would result in a distorted boat. Then, as each plank laps over and is fastened to its neighbor, the work must be done from the keel up, the sheerstrake being put on last. These lap fastenings are flush on the outside which prevents any planing after the planking is done, therefore each plank must be finished smooth as it is put on. The strakes are arranged and spilings taken in exactly the same way as for carvel except that the laps must be taken into consideration.

Referring to Plate 8 it will be seen that the upper edge of each plank is beveled so that the next one bears tight against it and the angle of this bevel depends on the form. Fig. 6 shows the condition where the mould is almost straight, as on the bottom, and the bevel is slight, while Fig. 7 shows it around the bilge where the greatest bevel will be. By holding a plank in position and placing a stick or rule across the corner as shown in Fig. 8, the amount to be taken off can be seen. The lap for thin planking is about ¾″ and a pencil line for the bevel should be gauged on the plank this distance from the edge.

At each mould, cut the bevel a short distance with a chisel or drawknife, then put the plank on a bench and bevel the full length, using these

short sections as guides. Where the planks fit in the stem rabbet and at the transom, the bevel must be so cut that the plank ends are flush. Start about a foot from the end and gradually change the plain bevel to a beveled rabbet, also bevel the lower edge of the adjoining strake so that at the end the joint will appear as in Fig. 10. This is necessary in order to avoid a shim edge on the outside which would be the case if the bevel was not rabbeted as in Fig. 11. After a plank is fitted, round off the outside lower corner and inside upper corner as shown.

If the form is perfectly fair and the planks properly fitted they will lie snug against the moulds, but it may be necessary to hold them, here and there, with slim wire nails driven through a block of wood or thick piece of leather. A handy clamp for holding the laps temporarily together while fitting is shown in Fig. 9. These are easily made and there should be six or eight on hand.

The planks are fastened to the stem and transom with brass screws and the laps riveted with copper nails spaced two to three inches, depending on the thickness of plank, and driven so the heads are flush on the outside. The spacing of nails is made with due reference to the frames so that they are fastened at each lap. The intermediate nails are driven as each plank is fitted but not

riveted until all the planks are on. Before fastening any plank to the stem or transom, lay a strand of candle wick so that it will be under the plank ends and as each strake is fastened, bed it in thick varnish or white lead colored to match the wood. This makes caulking unnecessary and the planks are therefore tightly fitted in the rabbet. As the fastenings are flush the finished planking cannot be planed, but go over all the nail and screw heads with a flat file, making them smooth and flush, then sandpaper thoroughly.

Ribband Carvel Planking. The thickness of material for this type of planking varies from 3/16″ to 7/8″ but the average is from 1/4″ to 1/2″. Battens are usually about the same thickness as the plank and from 1″ to 1 1/2″ wide, but if the frame spacing is wide they may be much heavier.

So far as the actual planking is concerned it is the same as plain carvel, the only difference being in the fitting and fastening. However, if the frames are light it is better to follow the suggestion given in the chapter on framing and plank from the keel up, fitting the stringers, clamps, etc., as you go. The thin planking usually associated with this type of construction will not permit much planing so that every precaution must be taken to keep it fair. If the planking is sufficiently thick, 3/8″ or more, the fasten-

ings can be countersunk and plugged, otherwise they are made flush on the outside which does not allow planing at all, and the very best workmanship is therefore essential to make a good job.

Each plank is spiled and fitted in the same manner as carvel except that the seams are made tight inside and out as no caulking will be done. When a plank is ready to go on, clamp it temporarily in place and mark the frames along its edge, for the center of the seam batten. The plank is then removed, pieces cut from the frame or liner, for the batten, and the batten fitted and fastened in place. See page 95. When a liner is used the short sections between battens are held with a couple of small wire nails. The plank is now put on and fastened to both frames and batten.

Fastenings in the frames are either riveted copper nails or brass screws; those in the batten riveted copper or round head brass screws put through the batten from the inside. Fig. 2, Plate 8, shows two frame fastenings in each plank, but if the planking is thin and the strakes fairly wide three fastenings are better. The proportions shown are about the limit for two. The intermediate fastenings between frames should be neatly spaced, the distance apart being determined by the thickness of planking. If the fastenings are flush the greatest care must be

exercised to plane the planks smooth, fair, and absolutely uniform in thickness before fastening. The heads of fastenings are filed smooth and the whole well sandpapered as mentioned for clinker planking.

Double Planking is employed when it is desired that a boat be strong, light, and of the best possible appearance. Cedar is nearly always used for the inner skin and varies from $\frac{1}{8}''$ to $\frac{3}{8}''$ in thickness. The outer skin may be of any suitable planking material and is from $\frac{1}{8}''$ to $\frac{3}{4}''$ in thickness. The general practice is to make the sheer and garboard strakes single with rabbeted edges as shown in Fig. 4, Plate 8, and then arrange the other strakes so that the seams in the outer skin are in the center of the inner planks. After the garboard is fastened, the adjoining strake of the inside skin is gotten out and fastened in place with a few small fastenings. The outer strake adjoining the garboard is then put on with a liberal coat of thick paint, thick varnish or waterproof glue under it.

The frame fastenings are the usual kind and the intermediate fastenings may be either screws or riveted nails. Screws are put in from the inside and the outside skin must be thick enough to hold them. Screws make the neatest job, especially in a bright finished boat, as there are

fewer plugs showing on the outside. The arrangement and spacing of the intermediate fastenings are governed by the thickness of plank and the spacing of frames, the object being to securely bind the skins together — particularly at the edges. All the fastenings are countersunk if the thickness of wood permits, otherwise they are made flush and the remarks regarding batten seam planking will apply for this also. If a fabric of any kind is to be laid between the skins, the inner skin must be completed, the material stretched over it and the outside planks put on, all of which makes the job much more difficult.

CHAPTER IX

DECK FRAMING AND DECKS

THE deck frame of a boat is made up of beams, carlines, breast hook, quarter knees, lodger bosom knees, hanging knees, and partners. See Plates 9 and 10. The various knees are made of hackmatack or oak and the other members of oak or chestnut.

The principal members are the beams, which extend from side to side and are fastened to the clamp, shelf if any, and the frame heads if the size permits. It is customary to fit one at each frame, except in special cases when the spacing may be greater. At the ends of deck openings such as cockpits, cabins, hatches, etc., and in the way of masts, extra heavy beams are fitted which are about double the "siding" (thickness fore and aft) of the regular beams. All beams are "crowned" or curved up in the center to an arc of a circle, which sheds water and stiffens the deck.

When the crown of deck is moderate the beams are usually sawed from planks, taking advantage

of any curve in the grain. If the crown is excessive, such as is often found in the forward decks of runabouts or the raised decks of small cruisers, it is better to bend the beams by steaming or use a combination of the two; some bent and some sawed. To bend them, lay out the curve on the floor and nail down blocks for a form, making the curve quicker as described for frames. Only one form need be made as several beams can be bent, one outside the other.

The first requisite is a "beam mould" or pattern which is made as follows. Refer to Fig. 2, Plate 9. Take a board six inches or so longer than the greatest beam and plane one edge straight. In the center draw the line A B square to the edge and with a radius equal to the required crown, draw the quarter circle C B. Divide A C into any number of equal spaces a b c, and C B into the same number of equal spaces d e f. A D, which is the half beam, is also divided into the same number of spaces 1 2 3 and at these points draw lines square to the edge. At 1 set off the distance a d; at 2 the distance b e and at 3 the distance c f. Repeat this on the other side of the center line and a curve drawn through the points obtained will be the crown of deck, which should be sawed out on the inside of the curve and planed true. If desired a second

curve may be drawn four or five inches from the first and the board cut to it, thus making both an inside and outside mould. This mould is used to line out the beams also to check the fitting of all the deck frame members.

It often happens that the crown must change slightly from beam to beam, in order to obtain the form desired or have a pleasing line at the center of deck. If the beams are bent the crown can be altered by straightening, but if the beams are sawed this of course cannot be done and the crown for each one must be obtained and laid out. A simple arrangement for doing this mechanically is shown in Fig. 3, Plate 9.

Set off the full breadth for any particular beam and at a and b drive wire nails partly in, then take two thin, straight pieces of wood, d and e, and secure them together at x, so that B equals the required crown. Now if these pieces are moved along with their edges bearing against nails a and b, a pencil placed at c will describe the required arc a c b.

Whether visible from the interior or not, it is better to plane the beams on all sides, then where they form a finish for the cabin the lower corners may be chamfered, rounded, or finished in any manner desired. This finish should not extend the full length but stop an inch or so from the

clamp or shelf. As mentioned in the chapter on framing there are numerous ways of arranging the clamp and shelf for the beams to land on. Plate 7 shows various combinations and there are others. In any case the beams must be neatly cut so that they have a good bearing and then well fastened. For large boats spikes or bolts are used; for smaller ones nails, bolts or screws. In regard to the fastening of deck beams it must be kept in mind that although the primary purpose is to support the deck a very important function is tying the sides of the boat together, so they must be well fastened.

Fit and fasten the main or heavy beams first and if any knees are located on them fit and fasten them also using clinch or screw bolts. Next put in the carlines which are the fore and aft members at the side of cabins, hatches, etc. As a rule carlines are about the same size as the heavy beams and are dovetailed into them as shown. This dovetail extends only about half the depth of beam. Very often the word carline is used to describe the beams of a cabin roof and this meaning must not be confused with the one given here. The beams in way of the carlines, called "short beams," are usually dovetailed or notched into the carlines, and fastened to the clamp in the same way as the regular beams. In

some designs the carlines in way of cockpit or cabin are fitted under the short beams and in others the carline is omitted and the coaming or cabin side depended on for the necessary strength. Bolts are often fitted every two or three beams connecting the carline and clamp.

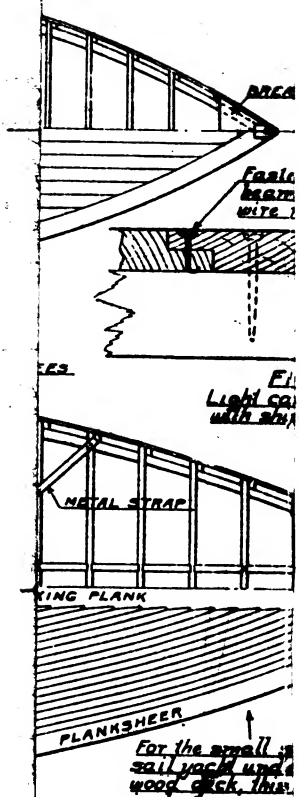
When fitting carlines and short beams, the beam mould should be frequently applied so that the proper crown is maintained and braces arranged to hold them in place. Fitting the regular beams requires no special mention except to be sure that the crown is right and the beams in line and fair on top. It is a good plan to fit a temporary girder underneath them at the center line, with posts to the keel, which is a guide in fitting the beams and stiffens them until the deck is laid. After the beams are all fitted cut off the frame heads flush with the top of them.

The breasthook is a block of wood, or a knee, arranged just abaft the stem. In decked boats it fits down on and is well fastened to the clamp and also extends out to the sheerstrakes which are well fastened to it. The top is curved to suit the crown of deck. When a breasthook is made of straight grained stuff, the grain generally runs fore and aft, and a couple of bolts should be put through it to prevent splitting. An undecked boat has the top of the breasthook flush with the

top of sheerstrake and the gunwale or clamp laps over and is fastened to it.

Quarter knees connect the sheerstrakes and clamps to the transom. They should be of natural crooks with the tops conforming to the deck crown and be scarphed to the piece which is fitted at the top of transom to take the deck. See Figs. 1 and 2, Plate 10. Well built boats have the plankshеer continue around the stern so that this nailing piece must be wide enough to take the ends of the deck planks.

Partners are reinforcements in way of mast holes and are made of heavy oak blocks let into and well fastened to the heavy beams, also very often backed up with knees. Fig. 2, Plate 10. Similar blocks are fitted in the way of manhole plates, deck plates, etc., but need not be so strong as they simply provide a place to fasten the deck. Wherever a cleat or other fitting is to be fastened, especially in light decks, a block should be fitted underneath to take the fastenings. Due to the racking strains of carrying sail, sail boats must have stronger and better braced decks than power boats and lightly constructed boats are generally fitted with diagonal straps of metal. These are let in flush on top of the deck beams, well fastened to them and also to the under side of deck with screws.


METAL STRAP
PLANKSHEER

DECKS

Decks are of two general kinds, i. e., all wood with caulked seams and wood covered with canvas. The caulked deck, to be good, must have considerable thickness to hold the caulking and seam filling; the planks must be narrow so that shrinkage will not open the seams or the planks warp; material must be the best and a plankshеer is necessary; all of which adds greatly to the cost. Then again the upkeep of a caulked deck is more troublesome and, unless kept in perfect shape, it is unsightly and apt to leak. On the other hand a canvased deck does not, in many cases, require a plankshеer; the material may be thinner, wider, and not so near perfect; the deck is watertight and an occasional coat of paint keeps it in good condition. All things considered I think the canvased deck is better for the cabin power boat and any type of sail boat the amateur might build. Open decked boats require a plankshеer anyway, so that the short end decks are best made of wood alone, as absolute water tightness is not so essential, which allows the deck planks to be thin and moderately wide. Figs. 1 and 3, Plate 10.

Caulked Decks. The plankshеer or covering board is practically a border for the deck all around and is made of yellow pine, oak, mahog-

any, or teak to match the outside finish. For small and medium boats it varies from three to six inches in width and is the same thickness as the deck. The several pieces are sawed out to shape and arranged so that the butts make good shift with those in the sheerstrake. The easiest way is to lay a board on the deck beams and mark along the sheerstrake for the outside, then when this is sawed, line the inside parallel to it. If the material is too stiff or the crown too great for this, make a template of thin wood.

For ordinary work the butts may be made between beams and butt blocks fitted, but when maximum strength is required and the thickness warrants, it should be hook scarphed and edge bolted. Forward it is fitted around the stem, the two sides joining at the center line; at the sides miter to the piece going across the stern. Fasten it well to the beams, quarter knees, breasthook, and sheerstrake with screws.

For the deck proper nothing is better than white pine, but it must be in long lengths and sawed so that the edge grain is up. For a bright deck, no defects such as knots, sap wood, stain, or checks are permissible, because unless such a deck is absolutely perfect a paint finish is preferable. The planks may be either laid straight fore and aft or "sprung" parallel to the plank-

sheer. If laid fore and aft the ends naturally come to a shim point where they meet the plank-sheer. Near the bow where the angle is not great, and the end can be fastened, this is no serious objection, but a little farther aft it will not do at all, so the point is cut off, making a "nib" about ½" wide and the plank-sheer notched out to suit. Fig. 7, Plate 10.

When the planks run parallel to the center, oak pieces must be fitted between the deck beams, at the inner edge of plank-sheer, to fasten the plank ends to. This style looks well on large flush deck boats whose cabin sides and cockpit are parallel to the center line, but for the smaller boat with cabin and cockpit sides parallel to the side of boat, the sprung deck is better.

The planks for a sprung deck must be narrow enough to bend and the ends are nibbed into a partner or king plank on the center line, Fig. 2, Plate 10, or finished herring-bone, Fig. 6, Plate 10. When planing deck planks take particular care to have the caulking seams uniform in width, as any opening of them with an iron, as described for planking, will ruin the appearance. The best way is to plane the edges square first, then bevel one edge about three-quarters the thickness from the top, thus leaving a bearing at the bottom which prevents driving the planks too close to-

gether. See Plate 9. Sometimes the butts are caulked which no doubt makes the most durable job, but a neater way is to plane the ends so that they fit perfectly and drive them together with varnish between, then fit a stop water. This is only possible with planks ¾″ or more in thickness.

Galvanized boat nails make the best fastening, using one or two at each beam depending on the width of the planks, the heads being countersunk and plugged. When the planks are very narrow they are often "blind fastened," by toeing nails through the edge into the beams, also edge nailing to the adjoining plank, between the beams. The latter should be wire nails driven near the bottom so as not to interfere with the caulking. See Plate 9.

Caulking is done in the usual way, but rather more depth allowed for the seam filling than is necessary for the outside of hull. Putty is often used in narrow seams, but it becomes hard in time and cracks if the deck shrinks as no doubt it will. There is a patent seam composition, used in the same manner but better than putty, which being elastic goes and comes with the wood. When using either putty or seam composition in a bright deck, first plane and sandpaper it, then give it one or two coats of spar varnish before filling the seams; otherwise it will be impossible

to remove the filling which is inadvertently smeared on the surface.

Some builders simplify this job and make a very neat finish by filling the seams before planing, which is all right providing the seams are well varnished first. When the seams are wide enough (⅛″ or more) regular deck glue, run in hot, makes a good job. In this case the glue must be in contact with the bare wood so that the planing and varnishing is done last. Either seam composition or deck glue may be obtained in several colors; black, white, and yellow being those in general use.

Canvas Decks. When decks are to be covered with canvas and a moulding fitted at the top of sheerstrake, a planksheer may be omitted and the deck plans run straight fore and aft, with the ends well fastened to the sheerstrake. They may be fairly wide, 4″ to 6″, and so long as the material is sound, slight defects do not matter. If the under side forms a finish in the cabin it is customary to use narrower stuff, tongued and grooved, with beveled joints on the under side. Fig. 4, Plate 10. In other cases a tongue and groove seam may be used or a ship lap with one or more fastenings in the lap, between the beams. Fig. 5, Plate 10. Cedar, white pine, or cypress are the materials mostly used, but the deck should

match or harmonize with the inside finish. Fastenings are galvanized boat nails or wire nails with the heads set just below the surface. Do not skimp the fastening as any curling of the boards will show through the canvas. When the deck is all laid, plane it fair and sandpaper thoroughly. Also plane the edge flush with the sheerstrake and slightly round the upper corner with sandpaper so that the canvas will not be cut when turned over. Give the deck a coat of thin lead paint and when dry putty all nail holes and inequalities.

The weight of canvas depends of course on the size and type of boat. #12 cotton duck is about right for light decks and small cabin tops, while #10 or #8 is better for larger boats where there is much walking. For hydroplanes and similar craft, wagon cover duck or heavy muslin answers very well. Cotton duck can be obtained in any width up to ten feet so that it is nearly always possible to put it on in one piece.

Choose a dry day for the work and be sure that the canvas is perfectly dry. Go over the deck again with sandpaper to remove any lumps of putty or other projections and dust it carefully, as even a small lump underneath the canvas will show plainly. Now give the deck a heavy coat of thick lead paint, well strained, and while wet stretch the canvas tight, fastening it with ½″ to

¾″ copper or galvanized tacks, spaced about 1½″. The canvas must be stretched uniformly tight and smooth, but not enough to strain the goods unduly.

A good scheme is to take a turn or two of each end around a stick, secure one end with a rope and pull the other, using a light tackle if the canvas is heavy, then stretch it sidewise by hand as you tack it fast. The outside is pulled over and tacked to the edge of deck if thick enough or to the top of sheerstrake. When the outside is secured all around, cut out any openings and tack around them.

The method of fastening the canvas around openings varies. In the case of a skylight or hatch, the canvas should eventually be turned up on the inside of the coaming, as the frame of such opening is called, so at this time put in only sufficient tacks to hold it and drive these in the deck so that the coaming will cover them. The same will apply around a cabin if the coaming goes on top of the deck, but if a cabin or cockpit coaming is fitted inside of the carline or clamp, the canvas should be turned down and tacked on the inside.

When all is secure give the canvas a coat of very thin paint. Some builders go over it with water just previous to painting, but the only advantage is a saving of material. A canvas deck

requires two or three coats in addition to this before it is in good shape. Another way is to use instead of paint a special waterproof glue made for this purpose. Spread the glue quickly on the wood with a wide brush and stretch the canvas, putting in enough fastenings to hold it, then go over it with a hot flat iron and finish fastening. Allow a few days for the glue to harden and paint as usual.

Where the canvas turns over the side it is covered with a moulding or wearing strip which is best fastened with brass screws. If iron is used for this, or the canvas, it will rust in time and make unsightly stains on the side of the boat. After the moulding is fitted trim off the canvas along its lower edge with a sharp knife.

THE END

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